

DESIGN AND IMPLEMENTATION OF A KNOWLEDGE-BASED SYSTEM FOR ANTIFRICTION BEARING SELECTION

by

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Design and Implementation of a Knowledge-Based System for Antifriction Bearing Selection

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by

Narendra Kumar Gupta

to the

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1995

|| Shri Ganeshaya Namah ||

Dedicated to my parents

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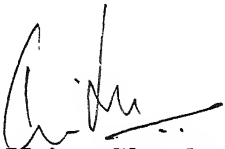
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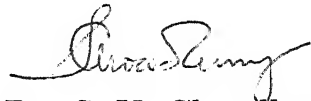
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CERTIFICATE

This is to certify that the work contained in this thesis entitled "**Design and Implementation of a Knowledge-Based System for Antifriction Bearing Selection**", by **Narendra Kumar Gupta**, has been carried out under our supervision and that this work has not been submitted elsewhere for the award of a degree.

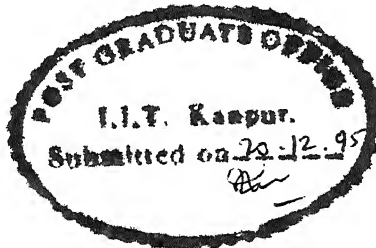


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ABSTRACT

A computer-aided knowledge based system, BEARSEL, is developed for the selection of antifriction bearings. For each bearing type, a data base which contains boundary dimensions, basic load ratings, limiting speeds, mass, company name and load factors of bearings is created. Knowledge about bearing type suitability, seals, lubrication, and fits and tolerances is also stored in separate data bases. Inputs required by the system are, speed, load, reliability, service life, operating temperature, dimensional constraints and desired level of few operating conditions.

Based on given inputs, system selects and ranks suitable bearing types and on selection of one type by the user, optimum size bearings are suggested. Recommendations are made for shaft and housing fits, lubrication and sealing methods. The system has six modules : Data-Input/Edit, Selection, Installation, Update, Print and Exit.

The system is adaptive and easily updatable. It is menu driven and user friendly, and is implemented on IBM compatible PC computer using DBase IV.2.

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NOMENCLATURE

a_1	Life adjustment factor for reliability
a_2	Life adjustment factor for material
a_3	Life adjustment factor for operating conditions
a_{23}	Life adjustment factor for material and operating conditions
B	Bearing width, mm
C	Dynamic load rating, N
C_o	Static load rating, N
C_{req}	Required dynamic load rating, N
c_p	Constant of contact pressure
D	Bearing outside diameter, mm
d	Bearing bore diameter, mm
d_w	Rolling element diameter, mm
e	Bearing factor
F_a	Axial bearing load, N
F_{amaz}	Admissible axial bearing load, N
F_r	Radial bearing load, N
FT	Temperature factor
f_s	Index of static stress
i	Number of rolling element rows
L_{10}	Basic rating life in millions of revolutions
L_{10h}	Basic rating life in operating hours
L_{10s}	Basic rating life in millions of kms.
L_{na}	Adjusted rating life
l_{eff}	Effective roller length, mm
n	Rotational speed, rpm
n_m	Mean bearing speed, rpm
P	Equivalent dynamic bearing load, N
P_m	Mean bearing load, N
P_o	Equivalent static bearing load, N
p	Exponent for life equation
$p_{o_{perm}}$	Permissible Hertzian contact pressure
q	Percentage of cycle/total time, %
SF	Shock factor
T	Operating temperature, °C

X	Radial load factor for dynamically stressed bearing
X_o	Radial load factor for statically stressed bearing
Y	Thrust/Axial load factor for dynamically stressed bearing
Y_o	Thrust/Axial load factor for statically stressed bearing
z	Number of rolling elements in a row
α_o	Contact angle
δ_b	Deformation, mm
α_o	Contact angle
μ	Coefficient of friction for bearing
ν	Kinematic viscosity of lubricant at specified temperature, mm^2/s
ν_1	Required Kinematic viscosity of lubricant at operating temperature, mm^2/s
ζ, η	Constants in viscosity equation

Chapter 1

Introduction

Selection of engineering components and products from manufacturers' catalogues is an area which is ideally suited to computerization. The major issues are as follows :

- The amount of technical information used to describe components and their performance characteristics is usually very large.
- While some data are in numeric and text format, data are also expressed as graphical charts or even as empirical relationships.
- Component and product selection inherently is a multi-stage and iterative decision process, and it requires performing some analysis at various stages of process to verify suitability in a specific application. Frequently, this can be a complex and tedious job to complete manually.
- The selection process often requires some degree of subjectivity while making choices.
- Various data, if suitably configured, may be stored as records in data files, rapidly accessed and retrieved using searching algorithms. Therefore, the scope for establishing heuristic rules from experienced engineers, building up a knowledge base and applying expert system techniques, lead to obvious advantages for the less experienced engineers exploiting such systems.

Of the engineering components, selection of suitable bearings for a given mechanical application constitutes a significant problem for a mechanical engineer. It is a complex problem and shares most of the factors mentioned above. Further, while the knowledge in this field is reasonably vast, expert opinion differ significantly. There is a need for computerized knowledge-based bearing selection system as a tool to systemize, conserve and spread this knowledge. Such a computerized selection system would offer the following advantages :

- A rapid selection procedure resulting into reduced time and cost.
- The best available bearing is readily identified both from technical considerations as well as commercial considerations (costs and availability).

- All bearing variants can be considered without prejudice.
- Optimum bearings can be specified without bias, thus impartiality of selection is maintained not only between manufacturers but amongst bearing types also.
- The use of 'standard' catalogue bearings is encouraged rather than the design and manufacture of 'specials'.
- Accuracy and reliability of results are improved.
- The system could be linked directly to other expert systems, which would further enhance the overall design process.

Rolling bearings are used in a variety of applications, ranging from gaint turbines to tiny electric motors. Generally speaking, the function of a bearing is to take up loads on a shaft so that the shaft is able to rotate freely without dislocation or damage. There are two main types of rolling bearings :

1. Roller bearings
2. Ball bearings

According to main load direction, bearings may also be classified as radial and thrust bearings. Bearing types can be subdivided into several subtypes, so the bearing taxonomy might be depicted as a tree (Fig. 1.1). This tree is a generalization vis-a-vis specialization hierarchy with property inheritance, where each node denotes a certain class of bearings.

1.1 Literature Review

Some basic research and software developement on bearing selection has already been carried out and are also in progress - both within academia and by bearing manufacturers themselves [1].

Many of the major manufacturers, with prime interest of promoting their own products, have developed selection software packages for potential engineering customers and 'in-house' use by their technical personnel. For example, the Swedish manufacturer, SKF has developed a system called **Cadalog**, the West German company, FAG has recently introduced its equivalent program called **WAS** and the Timken company has produced **Select-a-nalysis** [1].

Although these systems are relatively advanced, they do have some drawbacks. Because they only deal with an individual manufacturer's products they may not be totally objective in the selection procedure.

The preliminary work on computer aided selection procedure for rolling element bearings was done by J.Ellis [2] in 1974. The program developed was for use in conjunction with the manufacturer's (SKF) catalogue and computer was used only for calculations involved to check the suitability of previously selected bearing.

Ben O. McCutchan, Jr [3] published precised information based on experience and engineering judgement to select ball bearings. Similarly, J.K.Bailey, Jr [4] provided information for bearings operating at high speed.

Fagan [5] has reported the developement of an expert system for bearing selection. He used heuristics for the selection criteria. His grading scheme for selection is also very subjective, using grades such as very high, high, moderate and low. The output from the expert system is just one bearing type, rather than a couple of bearing types so that the user can make a choice on the basis of cost, availability etc. Also it does not calculate and suggest actual bearing size required.

Another expert system for bearing selection called **BETSY**, developed in cooperation with bearing manufacturing company SKF, Norway is reported by G.Hasle et al [6]. It is user friendly and uses both heuristics and calculations to suggest suitable bearing type as well as actual bearing size. But it is only applicable for industrial gearboxes.

Ahluwalia J. et al [7] presented a methodology for evaluating roller bearings in terms of their suitability for a given application. The method is based on multiple attribute decision making approach called **TOPSIS** (technique for order preference by similarity to the ideal solution). They considered taper and cylindrical roller bearings only and in fact has neglected the importance and necessity of considering suitability of a bearing type for a given application.

In the area of lubrication of rolling element bearings, specifically for the selection of oil viscosity at particular operating conditions, use of nomogram is the only method which has been reported so far in the literature [8–11].

1.2 Present Work

From the above study of literature and considering the deficiency of previous work, it is clear that a computer aided system for rolling element bearing selection for general applications and having the provision for including the products of leading bearing manufacturers to ensure impartiality and totality of the selection, is not available.

In the present work an attempt is made to develop a computer-aided knowledge-based system for the selection of the rolling element bearings to overcome these drawbacks by including the bearings of leading manufacturers and widening the spectrum of applicability as far as possible for different applications.

The objective of the system is to develop a three-stage selection procedure to enable a user first to narrow down the list of suitable bearing types by shortlisting the acceptable alternatives. Although the different types of bearings are designed for special purpose, several bearing types might be suitable for a given application. This calls for an attribute priority mechanism, and a method is devised to tradeoff between alternatives to make it possible to rank the alternatives according to their suitability for the desired application hence giving the choice to the user to select best suitable bearing type.

In the second stage, on the basis of the threshold values of the pertinent attributes (e.g. dynamic load rating, limiting speed etc.), a shortlist of bearings (for the selected bearing

type) is obtained. To achieve this, the database is scanned for the pertinent attributes, one at a time, to eliminate the bearing alternatives which have one or more pertinent attribute values that fall short of the minimum required values.

Suggestions are made for shaft and housing fits, lubrication and sealing methods in the final stage.

An interactive software package has been developed to assist an user to establish his/her priorities. Most of the design attributes (discussed in chapter 2) are considered in the selection procedure, either directly or indirectly. The system is completely menu driven and user friendly and is implemented on an IBM PC computer using dBase IV.2 . A PC is deliberately chosen because of its wide spread acceptance, flexibility and portability.

1.3 Organization of Thesis

In **chapter 2**, the system analysis is presented. The knowledge acquired from the catalogues, literature and expert opinions is represented using rules of non-algorithmic nature, mathematical expressions and tables.

In **chapter 3**, the design and implementation of the system on the computer is discussed. Flow of information and data, program algorithms and system architecture are briefly described.

In **chapter 4**, the results obtained by running the system for known applications are presented alongwith a discussion on the system performance.

In **chapter 5**, a conclusion is drawn and suggestions for future work are given.

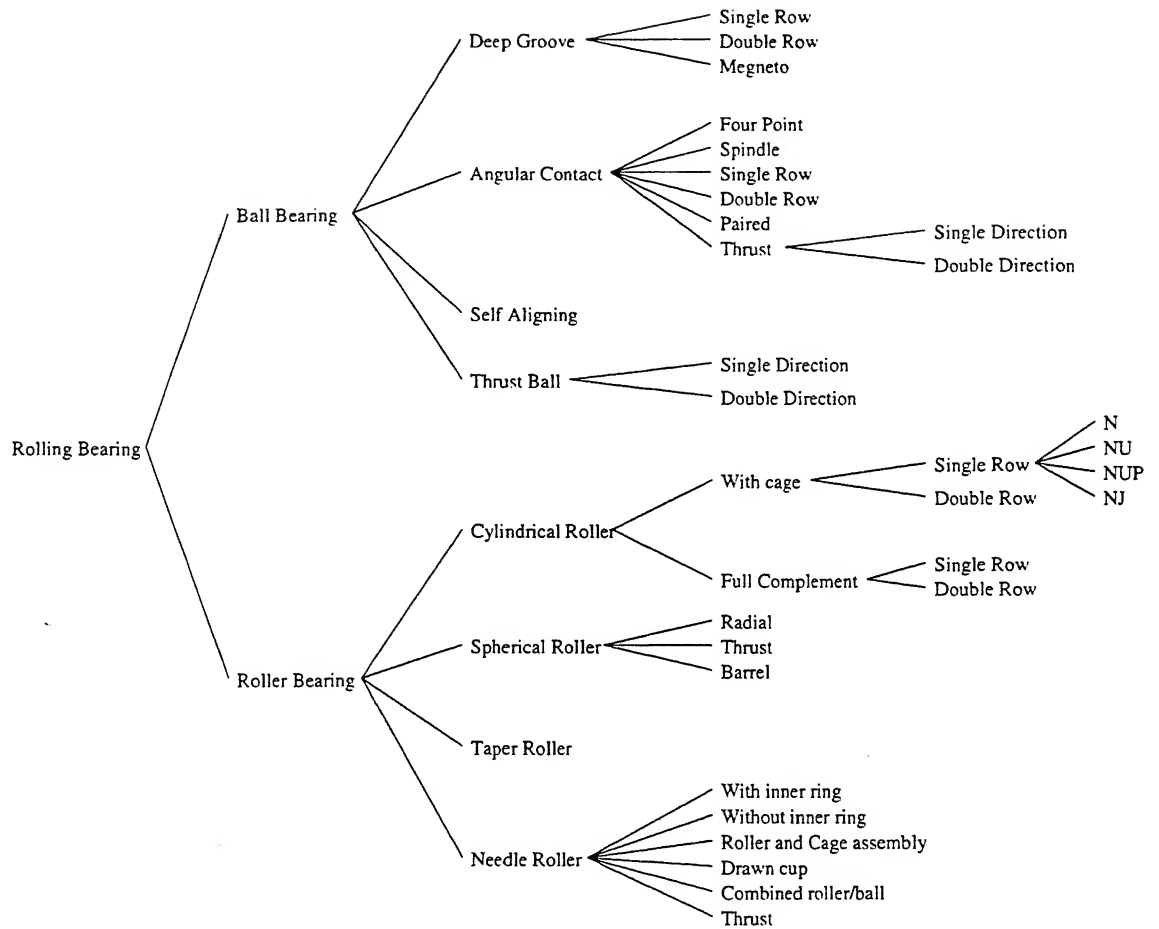


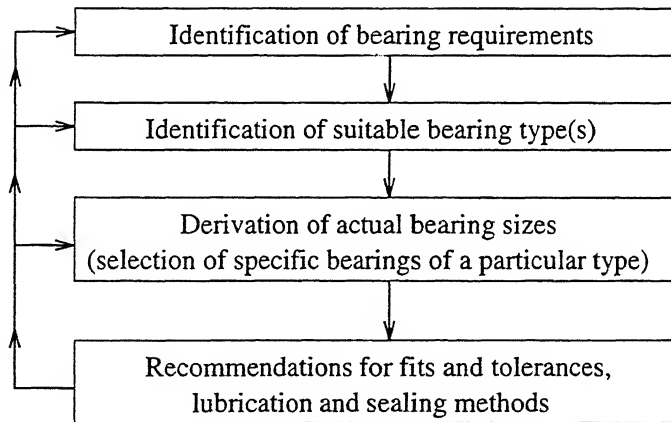
Figure 1.1: Bearing type taxonomy

Chapter 2

System Analysis

2.1 Introduction

The complete process of bearing selection can be summarised as follows :



This process is iterative. Heuristics give reasonable alternatives at each step. Pruning of the given alternatives is done after selection of bearing type by geometry, rating life and analysis considerations applied to the relevant bearings. The brief analysis of various steps involved in the process of selection is given in the following sections.

2.2 Identification of Bearing Requirements

The identification of various requirements and functions to be fulfilled by a bearing for a particular application is the first important step. They are defined in the form of factors. Their proper values, relative priorities and complexities play an important role in the process of selection. They are discussed in next section.

2.3 Factors for Identification of Possible Bearing Type(s)

Each type of bearing has characteristic features which make it particularly suitable for certain application. Several bearing types might be suitable for a given application. However, no such hard and fast rules exist for the selection of bearing types since several factors must be considered and assessed in relation to each other. The most important factors on which choice of bearing depend are listed below.

- Bearing loads,
- Vibration and shock loads,
- Rotational speed,
- Available space,
- Operating temperature,
- Shaft alignment,
- Permissible noise,
- Precision requirements,
- Rigidity,
- Availability and cost,
- Friction torque,
- Axial displacement,
- Mounting and dismounting.

Details of greatest importance in deciding type of bearing according to each factor are as follows :

2.3.1 Bearing Loads

Magnitude

Generally, roller bearings can carry greater loads than ball bearings of same external dimensions and are often the only choice for heavy loads and large diameter shafts. Ball bearings are mostly used for light and medium loads.

Direction (radial, axial, or combined)

Some of the bearing types can carry only radial loads, while some are only suitable for axial loads either in one direction or in both directions. Some can carry combined loads (radial and axial loads acting simultaneously). The ability of a bearing to carry an axial load depends on its angle of contact. The greater this angle the more suitable is the bearing for axial loads. Where the axial component of the combined load is large, a separate thrust bearing can be provided for carrying the axial load independently of the radial load. The suitability of all bearing types with respect to different load types is shown in Table 2.1 [10] and [12-16].

2.3.2 Vibration and Shock load

In addition to other loads, the presence of shock load and vibration also influence the choice of suitable bearing type. The suitability of bearing types in this respect is shown in Table 2.1 [3,10,12].

2.3.3 Rotational Speed

The speed of rotation of a rolling bearing is limited by the permissible operating temperature. Bearings with low frictional resistance and correspondingly low internal heat generation are most suitable for high rotational speeds. For radial loads, the highest bearing speeds are obtainable with deep groove ball or cylindrical roller bearings, and for combined loads with angular contact ball bearings (see Table 2.1).

2.3.4 Available Space

In many instances at least one of the main dimensions (usually the bore diameter) is predetermined by the machine design. Deep groove ball bearings are normally selected for small diameter shafts whereas, cylindrical roller and spherical roller bearings can be considered for large diameter shafts. If radial space is limited then bearings with small sectional height e.g. needle roller bearings etc. must be considered. Where axial space is limited, some series of single row cylindrical roller and deep groove ball bearings for radial and combined loads and, for axial loads, needle roller thrust and thrust ball bearings may be used.

Bearing Type	Load Capacity				Speed (max.)	Load Ratio F_a/F_r	Locating Capacity
	Radial	Axial	Combined	Shock			
ACBB1	G	< G	G	F	28000	-	G
ACBB2	G	< G >	G	F	15000	-	G
ACBB3	G	< G >	G	F	22000	-	G
ACTBBS	U	< G	P	P	4000	>> 2.13	-
ACTBBS	U	< G >	U	P	16000	-	-
BRB	E	< P >	F	G	7500	-	F
CRB1	F	U	U	G	24000	-	U
CRB3	F	< P	P	G	20000	<< 0.2	F
CRBDR	E	U	U	G	19000	-	U
CRTB	U	< G	U	E	4300	-	-
DGBB1	F	< F >	F	P	48000	-	G
DGBB2	F	< F	F	P	22000	<< 0.3	G
FPCBB	F	< G >	G	P	17000	>> 1.27	G
MB	F	< F	F	U	40000	-	U
NRB1	G	U	U	E	36000	-	U
NRB4	G	< P >	F	G	25000	<< 0.25	G
NRB5	P	< G	F	G	9500	-	F
NRTB	U	< G	U	E	4800	-	-
SABB	F	< P >	P	G	38000	-	F
SB	G	< G	G	P	80000	-	G
SRB1	E	< F >	G	E	9000	-	G
SRTB	P	< E	F	G	2600	>> 1.82	-
TBB1	U	< F	U	U	9500	-	-
TBB2	U	< F >	U	U	7000	-	-
TRB	E	< G	G	E	13000	-	E

* E excellent; G good; F fair; P poor; U unsuitable

* < single direction; <> double direction; >> greater than; << less than

* For full name of Bearing Type see Table 3.2

Table 2.1: Capabilities of different bearing types [10–16]

2.3.5 Operating Temperature

All rolling bearings can be used at temperature upto 120°C . At higher temperatures, the hardness of bearing materials and hence load carrying capacity reduces. For this, heat treated (stabilised for higher temperature) bearings are selected.

2.3.6 Shaft Alignment

In certain applications where the shaft can be misaligned relative to the housing, bearings capable of accomodating such misalignment are required. Misalignment can, for example, be caused by shaft deflection under load, bearings fitted in housings positioned on separate bases at a large distance or when it is impossible to machine the housing seatings in one setting. The permissible alignment angles and relative self aligning capabilities for various bearing types are listed in Tables 2.2 and 2.3 respectively [10].

Bearing type	Alignment angle
Self aligning ball bearings	4°
Barrel roller bearings	4°
Spherical roller bearings	2°
Spherical roller thrust bearings	$0.5^{\circ}-2^{\circ}$
Deep groove ball bearings	$5' - -15'$
Cylindrical roller bearings	$2' - -7'$
taper roller bearings	$1' - -3'$

Table 2.2: Permissible alignment angles [10,12]

2.3.7 Permissible Noise

Whilst rolling bearings have an intrinsically low noise level there are applications, for example electric motors running in hospitals, offices and homes, where this is an important factor in bearing selection. Deep groove ball bearings are normally the best choice. Suitability of various bearings types is listed in Table 2.3 .

2.3.8 Precision Requirements

Rolling bearings with a higher degree of precision than normal are required for shafts where stringent demands are made on running accuracy, e.g. machine tool spindles and also usually for shafts rotating at very high speeds. Suitability according to running accuracy of various bearing types is listed in Table 2.3 .

Bearing Type	Factors							
	Running Accuracy	Self Aligning Capacity	Radial Rigidity	Axial Rigidity	Running Quietness	Low Friction	Maintenance	Cost
ACBB1	E	P	G	G	G	P	G	G
ACBB2	E	U	G	G	G	G	P	F
ACBB3	E	U	G	E	G	F	P	F
ACTBB	E	U	E	G	P	E	P	G
BRB	G	E	F	G	U	F	P	P
CRB1	E	F	G	U	F	E	E	F
CRB3	G	F	G	U	U	E	E	P
CRBDR	E	F	E	U	U	G	P	P
CRTB	E	U	G	E	U	U	E	P
DGBB1	E	G	F	F	E	E	P	E
DGBB2	E	U	F	F	E	E	P	E
FPCBB	F	P	G	G	U	F	P	G
MB	E	F	F	F	E	G	G	E
NRB1	G	F	E	U	U	F	E	G
NRB4	F	U	G	F	U	F	F	F
NRB5	F	U	G	G	U	F	F	F
NRTB	F	U	U	E	U	P	E	F
SABB	G	E	F	F	U	E	P	G
SB	E	U	E	G	G	E	P	F
SRB1	G	E	F	G	U	G	P	P
SRTB	G	E	P	G	U	P	E	P
TBB1	E	U	U	G	U	E	E	E
TBB2	G	U	U	G	U	E	E	G
TRB	G	F	G	F	U	F	E	P

* E excellent; G good; F fair; P poor; U unsuitable

* For full name of Bearing Type see Table 3.2

Table 2.3: Suitability of different bearing types [10-20]

2.3.9 Rigidity

Elastic deformation in a loaded rolling bearing is very small and in most instances can be ignored. However bearing rigidity is important in some cases, e.g. for machine tool spindles. Because of the greater area of contact between the rolling elements and raceways, roller bearings deflect less than ball bearings. The rigidity can be increased by suitable preloading. The suitability is listed in Table 2.3 .

2.3.10 Friction

The frictional resistance of a rolling bearing depends on several factors like bearing load, speed and the properties of lubricant. Under normal operating conditions the friction torque M (measure of frictional resistance) is obtained from the equation [10] :

$$M = \mu Fd/2 \quad (2.1)$$

where :

μ = coefficient of friction for the bearing (Table 2.4)

F = bearing load, N

d = bearing bore diameter, mm

Where rubbing seals are used, having frictional resistance greater than that in bearing, seal friction is also taken into account. The suitability of various bearing types for low friction is listed in Table 2.3 .

Bearing type	μ
Self aligning ball bearings	0.0015
Spherical roller bearings	0.0018
Spherical roller thrust bearings	0.0018
Deep groove ball bearings	0.0015
Cylindrical roller bearings	0.0011
Taper roller bearings	0.0018
Angular contact ball bearings	0.0022
Needle roller bearings	0.0025
Thrust ball bearings	0.0013
Needle roller bearings	0.0025
Cylindrical roller thrust bearings	0.0040
Needle roller thrust bearings	0.0040

Table 2.4: Coefficient of friction [10]

2.3.11 Axial Displacement

The normal bearing arrangement consists of a locating (fixed) bearing and a non-locating (free) bearing. A bearing may be used as a locating, non-locating or cross-locating bearing depending on the application. The non-locating bearing can be displaced axially thus preventing cross location, e.g. by shaft expansion or contraction. The bearings having separable rings e.g. cylindrical roller (type NU and N) and needle roller bearings are particularly suitable for non locating applications. Their inner and outer rings can be mounted with interference fits. When using a non separable bearing, one of the ring should have clearance fit to allow axial freedom.

2.3.12 Mounting and Dismounting

The separable bearings are easier to install than non-separable bearings specially when an interference fit is to be used for both inner and outer rings or when frequent mounting and dismounting is required. It is easy to mount or withdraw bearings with tapered bore on tapered seating or using adapter or withdrawal sleeves on cylindrical shaft seatings. For suitability see Table 2.3 .

2.3.13 Availability and Cost

If more than one type of bearings are suitable for given application, cost and availability dominates in final selection of the bearing type.

2.4 Derivation of Actual Bearing Size

The size of a bearing to be used for a certain application is selected on the basis of its load carrying capacity in relation to the loads to be carried and the requirements regarding service life, reliability and other operating conditions. A certain degree of safety must exist to prevent excessive plastic deformation and premature material fatigue of the raceways and rolling elements.

A statically stressed bearing is rendered unserviceable by plastic deformation of rolling surfaces, whereas in dynamically stressed bearings, material fatigue causes these surfaces to flake. When necessary, wear is also taken into account. Unfavourable conditions such as dirt and lack of lubrication may increase wear and therefore clearance, to such an extent that the bearing ceases to fulfill its proper function.

2.4.1 Static Stressing

The term static stressing refers to bearing carrying a load when stationary or when subjected to small oscillating motion or rotating bearings subjected to heavy shock loads during fraction of a revolution. The load may be constant or variable. The bearings under

static load should not be stressed upto such an extent that plastic deformation causing indentation and flattened areas in the rolling surfaces, impair the rotation of the bearing.

Plastic Deformation

The plastic deformation in rolling bearing is expressed by the specific plastic deformation, defined as the ratio of sum of deformations of rolling element and raceway at one contact point δ_b to the rolling element diameter d_w . For a certain predetermined permissible magnitude of the specific plastic deformation, ratio δ_b/d_w , the plastic deformation is related to loading by following expressions [14] :

$$\text{Point contact} \quad p_{o_{perm}} = 3300 \cdot c_p^{3/10} \left(\frac{\delta_b}{d_w} \right)^{1/5} \quad [\text{N/mm}^2] \quad (2.2)$$

$$\text{Line contact} \quad p_{o_{perm}} = 2690 \cdot c_p^{2/5} \left(\frac{\delta_b}{d_w} \right)^{1/5} \quad [\text{N/mm}^2] \quad (2.3)$$

where :

$p_{o_{perm}}$ = permissible Hertzian contact pressure

c_p = constant of contact pressure according to contact conditions and can be determined from standard nomograms depending on curvature ratio, geometry and type of bearing.

Admissible Static Rolling Element Loading

Defined as permissible load Q_{perm} for which total deformation of rolling element and raceway does not exceed 0.01% of rolling element diameter, d_w , ensuring quiet running and full fatigue life of bearing. For $\delta_b/d_w = 0.0001$, Q_{perm} is given by [14] :

$$\text{Point contact} \quad Q_{perm} = \left(\frac{p_{o_{perm}}}{c_p} \right)^3 d_w^2 = k_s d_w^2 \quad (2.4)$$

$$\text{Line contact} \quad Q_{perm} = \left(\frac{p_{o_{perm}}}{c_p} \right)^2 d_w \cdot l_{eff} = k_s d_w \cdot l_{eff} \quad (2.5)$$

where :

l_{eff} = effective roller length, mm

Factor $k_s = \left(\frac{p_{o_{perm}}}{c_p} \right)^3 = \frac{1.43 \cdot 10^8}{c_p^{3.1}} \quad [\text{N/mm}^2] \quad \text{for point contact}$

$= \left(\frac{p_{o_{perm}}}{c_p} \right)^2 = \frac{1.82 \cdot 10^5}{c_p^{1.2}} \quad [\text{N/mm}^2] \quad \text{for line contact}$

Factor k_s depends upon c_p hence, curvature of rolling element and rolling path under highest stress. For different bearing types following approximate values may be considered For Deep groove ball and Angular contact ball bearings $k_s = 70$, for Thrust ball bearings and Roller bearings $k_s = 60$ & 200 respectively.

Static Load Rating C_o

The static load rating for bearings made of hardened bearing steel represents the load at which, under defined operating conditions, the maximum rolling element load Q_{max} equals the admissible rolling element load Q_{perm} or load which will produce permanent deformation of the rolling element and raceway on the most heavily stressed rolling element/raceway contact of 0.0001 times the rolling element diameter. In radial bearings, it corresponds to purely radial load and in thrust bearing to an axial load [14].

For radial and angular contact ball bearings,

$$Q_{max} = \left(\frac{5.0 \cdot C_o}{i \cdot z \cdot \cos \alpha_o} \right) \quad (2.6)$$

where :

i = number of rolling element rows

z = number of rolling element in a row

α_o = contact angle

After equating Q_{max} to Q_{perm} ,

$$C_o = \frac{k_s}{5.0} \cdot i \cdot z \cdot d_w^2 \cdot \cos \alpha_o = f_o \cdot i \cdot z \cdot d_w^2 \cdot \cos \alpha_o \quad [\text{N}] \quad (2.7)$$

similarly for radial and angular contact roller bearings,

$$C_o = \frac{k_s}{5.0} \cdot i \cdot z \cdot d_w \cdot l_{eff} \cdot \cos \alpha_o = f_o \cdot i \cdot z \cdot d_w \cdot l_{eff} \cdot \cos \alpha_o \quad [\text{N}] \quad (2.8)$$

Thrust ball bearings,

$$C_o = f_o \cdot z \cdot d_w^2 \cdot \sin \alpha_o \quad [\text{N}] \quad (2.9)$$

Thrust roller bearings,

$$C_o = f_o \cdot z \cdot d_w \cdot l_{eff} \cdot \sin \alpha_o \quad [\text{N}] \quad (2.10)$$

Here, f_o is a factor whose magnitude depends on the geometry (ratio $d_w \cdot \cos \alpha_o / T$) and type of bearing and may be obtained from standard tables. The values of static load rating, C_o , may directly be obtained from bearing tables provided by manufacturers.

Equivalent Static Load P_o

Loads comprising radial and axial components must be converted into an equivalent static bearing load which is defined as that radial load (for thrust bearings the axial load) which, if applied, would cause the same maximum plastic deformation as the actual loads. It is obtained by means of the general equation

$$P_o = X_o \cdot F_r + Y_o \cdot F_a \quad [\text{N}] \quad (2.11)$$

where :

F_r = actual radial load $[\text{N}]$

F_a = actual axial load [N]

X_o = radial load factor for the bearing (Table 2.5) [N]

Y_o = axial load factor for the bearing (Table 2.5) [N]

If calculated values of $P_o < F_r$, then $P_o = F_r$ is used.

Bearing type		Load factors			
<i>Radial bearings</i>		Single row		Double row	
		X_o	Y_o	X_o	Y_o
Deep groove ball bearings		0.6	0.5	0.6	0.5
Angular contact ball bearings	$\alpha_o = 20^\circ$	0.5	0.42	1	0.84
	$\alpha_o = 25^\circ$	0.5	0.38	1	0.76
	$\alpha_o = 30^\circ$	0.5	0.33	1	0.76
	$\alpha_o = 35^\circ$	0.5	0.29	1	0.58
	$\alpha_o = 40^\circ$	0.5	0.26	1	0.52
Spindle bearings	$F_a/F_r \leq 1.09$	1	0		
	$F_a/F_r > 1.09$	0.5	0.46		
Megneto bearings	$F_a/F_r \leq 0.8$	1	0		
	$F_a/F_r > 0.8$	0.6	0.5		
Four point contact bear.		1	0.58		
Self aligning ball, Spherical and Taper roller bearings		0.5	$0.22 \cdot \cot \alpha_o$	1	$0.44 \cdot \cot \alpha_o$
Barrel roller bearings		1	5		
<i>Thrust bearings</i>		X_o	Y_o		
Angular contact ball (SD)		0.92	1		
Spherical roller bearings		2.7	1		

Table 2.5: Radial load factor X_o and axial load factor Y_o for statically stressed bearings [10,14]

Index of Static Stressing f_s

Defined as ratio of static load rating, C_o , to equivalent static load, P_o .

$$f_s = \frac{C_o}{P_o} \quad (2.12)$$

Its minimum value ensures safety from excessive local deformation. The minimum values of f_s which may be used corresponding to permissible specific plastic deformation (depending on required running smoothness, slewing angle and shock load etc) are shown in Table 2.6. Exceptionally in case of spherical roller thrust bearing, minimum index $f_s \geq 2$ is used due to lip strength because a considerable part of the load is taken by the lip of shaft washer.

Applications	f_s
Smooth, vibration - free running	0.5
Average working conditions with normal demands on quiet running	1.0
Pronounced shock loads	1.5-2.0
high demand on quiet running	2.0
Spherical roller thrust bearings	≥ 2

Table 2.6: Static index f_s [14]

For statically stressed bearings, suitable sizes can be derived by determining the equivalent static load, P_o , and knowing the static load rating, C_o , and minimum index value, f_s .

2.4.2 Dynamic Stressing

It refers to loading of a rotating bearing. The load may be constant or variable.

Material Fatigue, Failure Probability and Distribution

Experience and experiment results show the occurrence of fatigue phenomena on the operating surfaces of identical dynamically stressed bearings with similar operating conditions after different periods of operation. This makes it impossible to state the probable fatigue life of an individual bearing and can only be made for a large group of identical bearings stressed in same manner. The fatigue behavior of a large bearing group can be assessed satisfactorily by means of Weibull plot which gives statistical distribution of fatigue lives by associating running time with failure probability (proportion of bearings which have failed up to this time).

Fatigue Life or Rating Life Equation

As per ISO recommendation R281, fatigue life (rating life) of a sufficiently large number of dimensionally identical bearings is expressed by the number of revolutions or number of hours at constant speed reached or exceeded by 90% of bearings of this group before the first signs of material fatigue appear. The rating life considerably increases with decrease in bearing load and its relationship with dynamic load rating, C , and bearing load, P , for the bearings made of conventional bearing steel, operating under most favourable conditions (correct mounting and lubrication, reliable sealing, absence of extreme temperature and contamination etc.), is expressed by the rating life equation [18] :

$$L_{10} = \left(\frac{C}{P}\right)^p \quad (2.13)$$

where :

L_{10} = basic rating life in millions of revolutions

C = basic dynamic load rating, N

P = equivalent dynamic bearing load, N

p = exponent for life equation (3 for ball and 10/3 for roller bearings).

For bearings operating at constant speed it may be more convenient to deal with the basic rating life expressed in operating hours using the equation [10] :

$$L_{10h} = \frac{1000000}{60 \cdot n} \left(\frac{C}{P} \right)^p \quad (2.14)$$

where :

L_{10h} = basic rating life in operating hours

n = rotational speed, rev/min

The values of L_{10} or L_{10h} corresponding to values of C/P and/or n can be found by using chart shown in Fig 2.1 . For road and rail bearings, especially wheel hub and axle bearings, it is preferable to express the life in terms of kilometers travelled and is obtained by equation [10] :

$$L_{10s} = \frac{\pi D}{1000} \left(\frac{C}{P} \right)^p \quad (2.15)$$

where :

L_{10s} = basic rating life in millions of kilometers

D = wheel diameter, m

For bearings made of materials other than the conventional steel and/or operating at abnormal conditions the rating life is expressed by adjusted rating life equation [18] :

$$L_{na} = a_1 \cdot a_2 \cdot a_3 \left(\frac{C}{P} \right)^p \quad (2.16)$$

where

L_{na} = adjusted rating life in millions of revolutions

n = index representing the difference between the requisite reliability and 100%

a_1, a_2, a_3 = life adjustment factors.

Life Adjustment Factors

a_1 : The factor for reliability is used to determine lives other than the L_{10} life, i.e. lives which are attained or exceeded with a greater probability than 90% . Values of a_1 are listed in Table 2.7 .

a_2 : The factor for material is used to take into account the effect of improvements made to conventional steel used by bearing manufacturers. Generally values of $a_2 > 1$ are used. Even higher values can be applied when special steels e.g. electro slag refined (ESR) or vacuum arc remelted (VAR) steels are used.

a_3 : The factor for operating condition is essentially determined by bearing lubrication and operating temperature.

a_{23} : The combined factor for material and lubrication, by replacing a_2 and a_3 , since both are interrelated, may be used. This can be obtained from standard charts available.

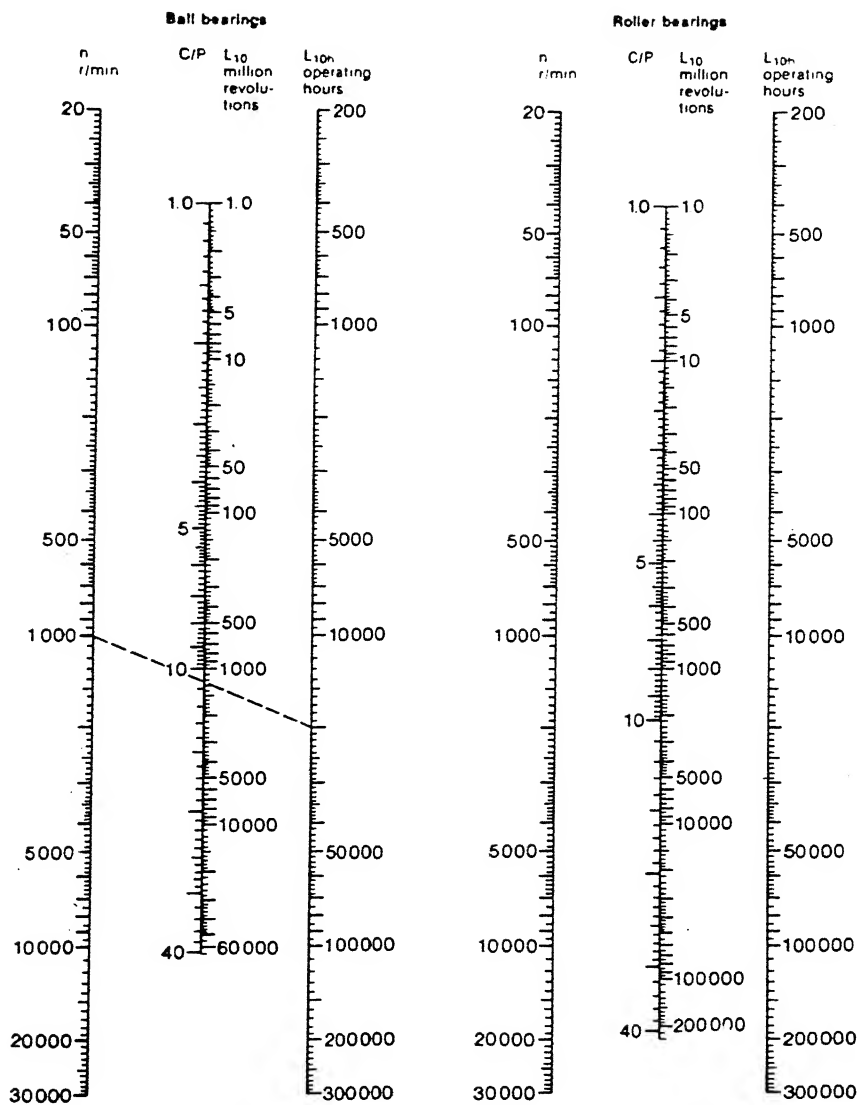


Figure 2.1: Life calculation chart [10]

Reliability %	a_1
90-94	1
95	0.62
96	0.53
97	0.44
98	0.33
99	0.21

Table 2.7: Values of life adjustment factor a_1 [10]

Requisite Basic Rating Life

When determining bearing sizes, it is essential that the required basic rating life for the application under consideration is known. This usually depends on the type of machine and the requirements regarding duration of service and operation reliability. In absence of previous experience the values given in Tables 2.8 and 2.9 can be used.

Dynamic Load Rating C

It corresponds to a constant bearing load (purely radial for radial bearings and purely axial applied centrally for thrust bearings) at which a large number of identical bearings reaches a rating life of one million revolutions. For a particular bearing dynamic load rating, C , can be calculated as follows [14,15] :

For radial ball bearings :

For bearings with ball diameter $d_w \leq 25.4 \text{ mm}$

$$C = f_c \cdot (i \cdot \cos \alpha_o)^{0.7} \cdot z^{2/3} \cdot d_w^{1.8} \quad [\text{N}] \quad (2.17)$$

and for $d_w > 25.4 \text{ mm}$

$$C = f_c \cdot (i \cdot \cos \alpha_o)^{0.7} \cdot z^{2/3} \cdot 3.647 d_w^{1.4} \quad [\text{N}] \quad (2.18)$$

For radial roller bearings :

$$C = f_c \cdot (i \cdot l_{eff} \cdot \cos \alpha_o)^{7/9} \cdot z^{3/4} \cdot d_w^{29/27} \quad [\text{N}] \quad (2.19)$$

For thrust ball bearings :

For single & double acting thru. ball bearings ($\alpha_o = 90^\circ$)

$$\text{for } d_w \leq 25.4 \text{ mm} \quad C = f_c \cdot z^{2/3} \cdot d_w^{1.8} \quad [\text{N}] \quad (2.20)$$

$$\text{and for } d_w > 25.4 \text{ mm} \quad C = f_c \cdot z^{2/3} \cdot 3.647 d_w^{1.4} \quad [\text{N}] \quad (2.21)$$

For angular contact thrust ball bearings ($\alpha_o < 90^\circ$)

$$\text{for } d_w \leq 25.4 \text{ mm} \quad C = f_c \cdot (\cos \alpha_o)^{0.7} \cdot \tan \alpha_o \cdot z^{2/3} \cdot d_w^{1.8} \quad [\text{N}] \quad (2.22)$$

Class of machines	L_{10h} operating hours
Domestic machines, agricultural machines, instruments, technical apparatus for medical use	300 to 3000
Machines used for short periods or intermittently: Electric hand tools, lifting tackles in workshops, construction machines	3000 to 8000
Machines used for short periods or intermittently with high operational reliability : Lifts, cranes, bales	8000 to 12000
Machines used for 8 hours per day but not always fully utilised: Gear drives for general purposes, electric motors for industrial use, rotary crushers etc.	10000 to 25000
Machines used for 8 hours per day and fully utilised: Machine tools, woodworking m/cs, machines for the engineering industry, cranes for bulk materials fans conveyor belts, printing equipments, centrifuges etc.	20000 to 30000
Machines for continuous use 24 hours per day: Rolling mili gear units, medium sized electircal machinery, compressors, pumps, textile machinery	40000 to 50000
Water works machinery, rotary furnaces,cable stradding machines, propulsion machinery for ocean vessels	60000 to 100000
Machines for continuous use 24 hours per day with high operational reliability: Pulp & paper making machines large electric machinery, mine pumps, power plant machinery, tunnel shaft bearings etc	≈ 1000000

Table 2.8: Requisite basic rating life L_{10h} for different classes of machines [10,12]

Type of vehicle	L_{10s} millions of km
Wheel hub bearings for road vehicles :	
Private cars	0.1
Commercial vehicles, buses etc.	0.2 to 0.3
Axlebox bearings for rail vehicles :	
Goods wagons	0.8
Suburban stock, tramcars	1.5
Main line passenger carriages	3
Main line motor units	3 to 4
Main line diesel and electric locomotives	3 to 5

Table 2.9: Requisite basic rating life L_{10s} for road and rail vehicles [10,12]

$$\text{and for } d_w > 25.4 \text{ mm} \quad C = f_c \cdot (\cos \alpha_o)^{0.7} \cdot \tan \alpha_o \cdot z^{2/3} \cdot 3.647 d_w^{1.4} \quad [\text{N}] \quad (2.23)$$

For thrust roller bearings :

For single & double acting roller thrust bearings ($\alpha_o = 90^\circ$)

$$C = f_c \cdot l_{eff}^{7/9} \cdot z^{3/4} \cdot d_w^{29/27} \quad [\text{N}] \quad (2.24)$$

and for $\alpha_o < 90^\circ$ (spherical roller thrust bearing)

$$C = f_c \cdot (l_{eff} \cdot \cos \alpha_o)^{0.7} \cdot \tan \alpha_o \cdot z^{3/4} \cdot d_w^{29/27} \quad [\text{N}] \quad (2.25)$$

in which f_c is a factor whose values depend on geometry of bearing components, thier accuracy, material and type of bearing and are available in standard tables provided by manufacturers. The values of dynamic load rating, C , for each bearing are also available from bearing tables.

Influence of temperature on dynamic load rating : At elevated temperatures the hardness of bearing materials is reduced and the dynamic load carrying capacity is also reduced as a consequence. special heat treatment to ensure dimensional stability also results in a reduction of hardness. This effect is taken into account by multiplying the basic dynamic load rating, C , by a temperature factor, FT , which is listed in Table 2.10 .

Equivalent Dynamic Load P

In many bearing applications the load acts on the bearing obliquely or changes its magnitude and does not satisfy the assumption of constant load made in rating life equation. In such cases a hypothetical load (equivalent bearing load P), constant in both magnitude and direction, acting radially on radial bearings or axially on thrust bearings, having same

Bearing temperature ($^{\circ}\text{C}$)	150	200	250	300
Temperature factor FT	1.0	0.9	0.75	0.6

Table 2.10: Temperature factor FT [10]

influence on the bearing life as the actual loads, is determined for rating life calculations, representing an equivalent stress.

The equivalent dynamic bearing load for constant and variable loads is calculated as follows [14] :

Constant bearing load

Radial bearings : If the magnitude and direction of the resultant load is constant, the equivalent dynamic load is obtained from the general equation :

$$P = X \cdot F_r + Y \cdot F_a \quad [\text{N}] \quad (2.26)$$

where :

X = radial load factor for the bearing under dynamic load

Y = axial load factor for the bearing under dynamic load

The values of X, Y and other data required in calculation of P are shown in Table 2.11 . In case of single row radial bearings the axial load is not significant until the ratio F_a/F_r exceeds a specified value e . With double row radial bearings even light axial loads are significant. In deep groove ball bearings, subjected to axial load, a contact angle $\alpha > 0^{\circ}$ occurs depending on the magnitude of load. This is taken into account by relating factors X and Y with axial load, F_a , and static load rating, C_o .

Thrust bearings : Bearings having contact angle $\alpha_o = 90^{\circ}$ can carry axial loads only whereas, for bearings having $\alpha_o \neq 90^{\circ}$, same equation, as for radial bearings, can be used with values of X and Y shown in Table 2.11 .

Variable bearing load

In many bearing arrangements, load and rotary speed change either randomly or according to work cycle and in order to calculate the equivalent bearing load, a constant mean load P_m having the same influence on the bearing (same fatigue life at mean speed) as the actual variable load is determined. The approximate constant mean load for different load and speed conditions may be obtained as follows [14] :

- When load and speed both are variable, the load and speed curves are approximated by a series of individual loads and speeds of a certain duration $q\%$ (stepped characteristics) as shown in Fig 2.2 and the mean rotary speed, n_m , computed as weighted mean (with weightages as percentage of cycle/total time), is given by :

$$n_m = n_1 \cdot \frac{q_1}{100} + n_2 \cdot \frac{q_2}{100} + \dots \quad [\text{rpm}] \quad (2.27)$$

Bearing type		e	Single-row				double-row			
	$\frac{F_a}{C_o}$		$\frac{F_a}{F_r} \leq e$		$\frac{F_a}{F_r} > e$		$\frac{F_a}{F_r} \leq e$		$\frac{F_a}{F_r} > e$	
<i>Radial bearings</i>			X	Y	X	Y	X	Y	X	Y
Deep groove ball bearings	0.025	0.22	1	0	0.56	2	1	1 (for $\frac{F_a}{F_r} \leq 0.3$)		
	0.04	0.24	1	0	0.56	1.8				
	0.07	0.27	1	0	0.56	1.6				
	0.13	0.31	1	0	0.56	1.4				
	0.25	0.37	1	0	0.56	1.2				
	0.50	0.45	1	0	0.56	1				
Spindle bearings	0.025	0.4	1	0	0.44	1.42	1	1		
	0.04	0.42	1	0	0.44	1.36				
	0.07	0.44	1	0	0.44	1.27				
	0.13	0.48	1	0	0.44	1.16				
	0.25	0.53	1	0	0.44	1.05				
	0.50	0.56	1	0	0.44	1				
Angular contact ball bearings	$\alpha_o = 20^\circ$	0.57	1	0	0.43	1	1	1.09	0.70	1.63
	$\alpha_o = 25^\circ$	0.57	1	0	0.43	1	1	1.09	0.70	1.63
	$\alpha_o = 30^\circ$	0.57	1	0	0.43	1	1	1.09	0.70	1.63
	$\alpha_o = 35^\circ$	0.57	1	0	0.43	1	1	1.09	0.70	1.63
	$\alpha_o = 40^\circ$	0.57	1	0	0.43	1	1	1.09	0.70	1.63
Megneto bear.		0.20	1	0	0.50	2.5				
Self aligning ball bearings		1.5· $\tan \alpha_o$					1	0.42· $\cot \alpha_o$	0.65	0.65· $\cot \alpha_o$
Spherical roller bearings		1.5· $\tan \alpha_o$					1	0.45· $\cot \alpha_o$	0.67	0.67· $\cot \alpha_o$
Taper roller bearings		1.5· $\tan \alpha_o$	1	0	0.40	0.4· $\cot \alpha_o$				
Barrel roller bearings			1	9.5	1	9.5				
Thrust bearings			X	Y	X	Y	X	Y	X	Y
Angular cont. ball bearings			0.92	1	0.92	1				
Spherical roll.		1.8			1.2	1				

Table 2.11: Radial load factor X and axial load factor Y for dynamically stressed bearings [10,12,14]

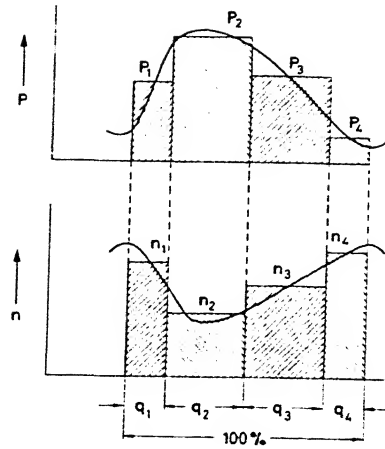


Figure 2.2: Step load approximation

and similarly the mean load P_m is given by :

$$P_m = \left(P_1^p \cdot \frac{n_1}{n_m} \cdot \frac{q_1}{100} + P_2^p \cdot \frac{n_2}{n_m} \cdot \frac{q_2}{100} + \dots \right)^{1/p} \quad [\text{N}] \quad (2.28)$$

where P_1, P_2, \dots and n_1, n_2, \dots are the constant loads and speeds during q_1, q_2, \dots durations respectively. p is the exponent used in life equation.

- When load is variable and speed is constant,

$$P_m = \left(P_1^p \cdot \frac{q_1}{100} + P_2^p \cdot \frac{q_2}{100} + \dots \right)^{1/p} \quad [\text{N}] \quad (2.29)$$

- When speed and direction of loading are constant and assuming load to be fluctuating linearly between P_{max} and P_{min} ,

$$P_m = \frac{P_{min} + 2 P_{max}}{3} \quad [\text{N}] \quad (2.30)$$

- When the bearing load comprises a load, P_2 , of constant magnitude and direction, e.g. the weight of rotor, and a rotary constant load, P_1 , e.g. unbalance, the mean load is obtained by

$$P_m = P_2 \left[1 + 0.5 \left(\frac{P_1}{P_2} \right)^2 \right] \quad [\text{N}] \quad (2.31)$$

If the variable load acts in radial direction for radial bearings and in axial direction for thrust bearings, the equivalent bearing load $P = P_m$. However, if the load acts in any other direction the equivalent load is calculated using the general equation

$$P = X \cdot F_r + Y \cdot F_a \quad [\text{N}] \quad (2.32)$$

in which, F_r and F_a are the radial and axial components of the mean load P_m or calculated separately.

Influence of shock load : In addition to the forces taken into account in calculation of equivalent bearing load, shock loads may occur in many applications. As it is very difficult to calculate accurate values of shock loads, its influence on bearing life is accounted by applying a shock factor SF to the equivalent bearing load (see Table 2.12).

Type of duty	shock factor
Almost shock free service: General purpose chain and gear drives; coal, sand and ore conveyors; rotary compressors; electric motors, auto pinions, front wheels, transmissions and rear wheels that are independently suspended, engines, farm machinery, household appliances.	1 to 1.2
Light shock service: Fans; centrifugal blowers; mixers; continuously operated cranes; belt tension devices and applications in which dead weight is the principal load; ground gears, truck and bus front and rear wheels.	1.2 to 1.5
Moderate shock service: Dryers; ball mills; trunnion wheel applications without tires; truck and bus front wheels; multiple stage pumps; milled gears.	1.5 to 2.0
Heavy shock service: Foundry shake-outs; oscillating conveyors; reciprocating compressors and pumps; crushers; hammer mills and impact pulverizers, auto and truck differentials and transaxles, press and shear flywheels.	2.0 to 3.0

Table 2.12: Shock factor FS [3]

Required Dynamic Load Rating C_{req}

The minimum basic dynamic load rating (required), C_{req} , necessary to reach the required bearing life can be calculated by using following equations :

$$\begin{aligned}
 C_{req} &= \left[\frac{60 n L_{10h}}{10^6 a_1} \right]^{1/p} \cdot P \cdot \frac{FS}{FT} \\
 &= \left[\frac{1000 L_{10s}}{\pi D a_1} \right]^{1/p} \cdot P \cdot \frac{FS}{FT}
 \end{aligned} \tag{2.33}$$

2.4.3 Admissible Axial Loads

In some types of bearings the axial load carrying capacity is not governed by the fatigue characteristics of the material, but depends on the ability of the sliding surfaces of the

rolling elements and guide flanges or raceway to carry the load. The admissible axial load $F_{a_{max}}$ for such bearing types are as follows [10] :

Deep groove ball bearing

$$\frac{F_{a_{max}}}{C_o} < 0.50 \quad \text{if bearing bore diameter } d \leq 60 \text{ mm} \quad (2.34)$$

$$< 0.75 \quad \text{otherwise} \quad (2.35)$$

Cylindrical roller bearing (type NJ, NUP and HJ)

$$\frac{F_a}{F_r} < 0.13 \quad \text{for series 02 and 03} \quad (2.36)$$

$$< 0.20 \quad \text{for series 22 and 23} \quad (2.37)$$

Needle roller and ball assembly

$$\frac{F_a}{F_r} \leq 0.25 \quad (2.38)$$

2.4.4 Minimum Loading of Thrust Bearings

In thrust bearings, rotating at high speeds, the centrifugal forces and gyroscopic moments acting on the rolling elements can give rise to sliding between the rolling elements and raceways. To prevent damage, the bearing must be subjected to a minimum continuous axial load. The minimum required axial load for different bearings are as follows [10,14] :
Thrust ball and cylindrical roller thrust bearings :

$$F_a > A \left(\frac{n}{1000} \right)^2 \quad (2.39)$$

Needle roller thrust bearings :

$$F_a = \frac{C_o}{1000} \quad (2.40)$$

Spherical roller thrust bearings with combined load :

$$\frac{C_o}{1000} \leq F_a < 1.8 F_r + A \left(\frac{n}{1000} \right)^2 \quad (2.41)$$

where F_a is minimum axial load and A is minimum load factor specified in bearing tables.

The sizes of suitable dynamically stressed bearings are derived by calculating required dynamic load rating, C_{req} , (using Equation 2.33) and then bearings having values of dynamic load rating, C , higher than the C_{req} are selected. Which are further checked for static load rating and all necessary conditions (e.g. admissible and minimum loads etc).

Finally bearings satisfying limiting speed criteria and dimensional requirements are short-listed. Calculation procedure is shown in a system flow chart in Fig.2.3 .

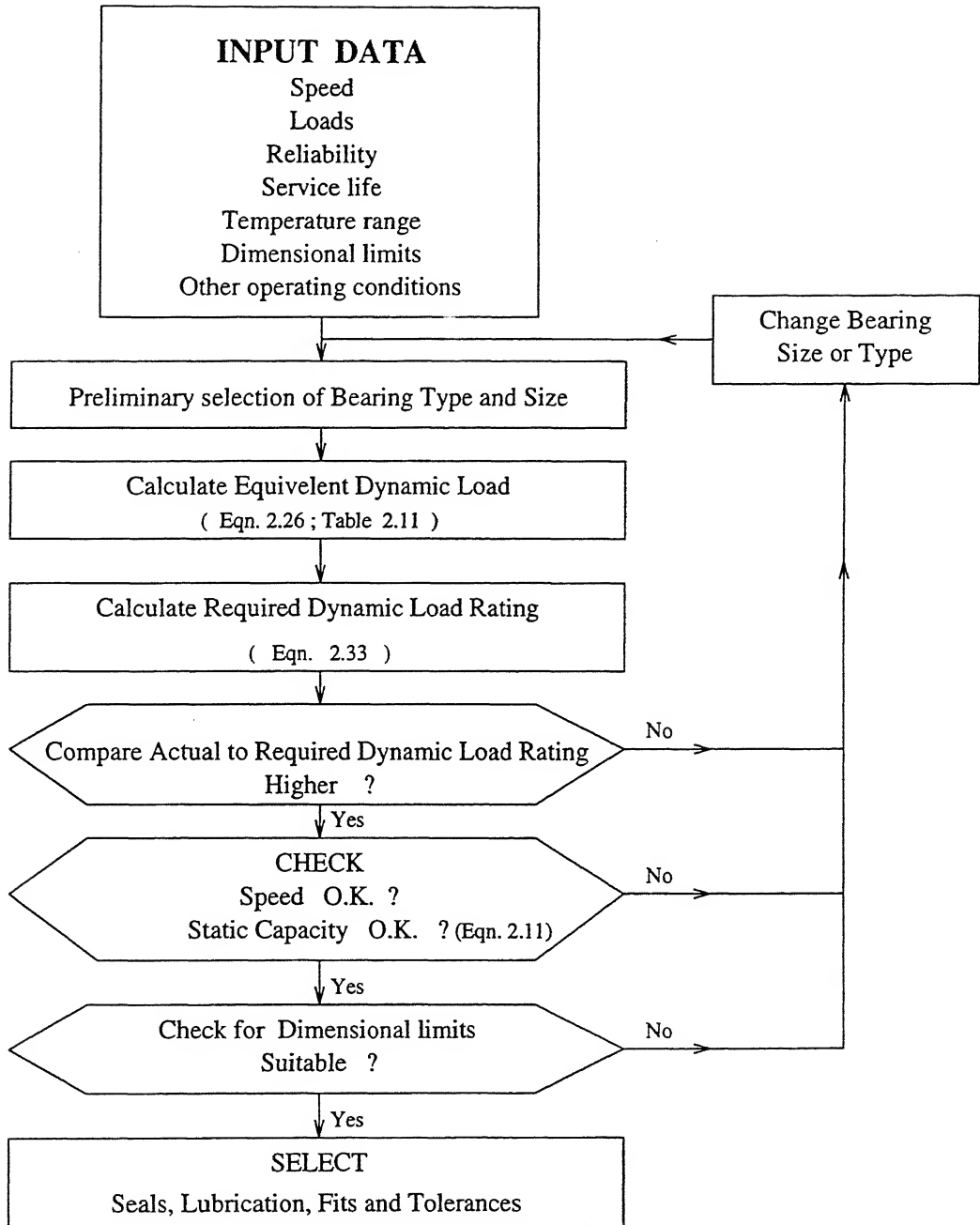


Figure 2.3: System flow chart

2.5 Selection of Lubrication Method

Rolling bearings must be lubricated to prevent metallic contact between the rolling elements, raceways and cage and also to protect from corrosion and wear. The most favourable running temperature is obtained when the minimum of lubricant, necessary to ensure reliable lubrication, is used. However, quantity also depend on sealing and cooling requirements. Lubricating properties of the lubricants deteriorate as a result of ageing and mechanical working and all lubricants become contaminated in service and therefore, must be replenished or changed from time to time.

Rolling bearings may be lubricated with grease or oil and in special cases with a solid lubricant. The choice of lubricant depends primarily on the temperature range, bearing size and operating speeds for which it is required. The summarised information regarding lubricant selection is shown in Table 2.13 .

<i>Factor affecting the choice</i>	<i>Use grease</i>	<i>Use oil</i>
Temperature	Up to 120°C—with special greases or short relubrication intervals up to 200/220°C	Up to bulk oil temperature of 90°C or bearing temperature of 200°C—these temperatures may be exceeded with special oils
Speed factor*	Up to dn factors of 300 000/350 000 (depending on design)	Up to dn factors of 450 000/500 000 (depending on type of bearing)
Load	Low to moderate	All loads up to maximum
Bearing design	Not for asymmetrical spherical roller thrust bearings	All types
Housing design	Relatively simple	More complex seals and feeding devices necessary
Long periods without attention	Yes, depends on operating conditions, especially temperature	No
Central oil supply for other machine elements	No—cannot transfer heat efficiently or operate hydraulic systems	Yes
Lowest torque	When properly packed can be lower than oil on which the grease is based	For lowest torques use a circulating system with scavenge pumps or oil mist
Dirty conditions	Yes—proper design prevents entry of contaminants	Yes, if circulating system with filtration

* dn factor (bearing bore (mm) \times speed (rev/min)).

Note: for large bearings (> 65 mm bore) use nd_m (d_m is the arithmetic mean of outer diameter and bore (mm)).

Table 2.13: Selection of the lubricant [8]

2.5.1 Grease Lubrication

Generally used where bearings operate under normal conditions. Grease has certain advantages over oil like simpler housing design, less maintenance, better sealing against dirt

and moisture and less difficulty with leakage. In general, the free space in the bearing and housing should only be partly filled with grease (30–50%). Overfilling may cause overheating.

Selection

The principle factors governing the selection of grease are speed, temperature, load, bearing size and environment alongwith the properties of grease like consistency (quoted in National Lubricating Grease Institute (NLGI) scale), temperature range, load carrying ability and rust inhibiting properties. For heavily loaded bearings grease containing EP (extreme pressure) additives are used.

Relubrication Interval

The period during which a grease lubricated bearing will function satisfactorily without relubrication is dependent on the bearing type, size, speed, operating temperature and the grease used. The relubrication interval (hours of operation) may either be obtained from the chart shown in Fig. 2.4 or calculated by following expression [9] :

$$t_f = k \left(\frac{14 \cdot 10^6}{n \cdot \sqrt{d}} - 4d \right) \quad (2.42)$$

where :

t_f = service life of grease or relubrication interval in hours

k = factor, depend on type of bearing

Amount of Grease

The required amount of grease may be calculated from expression [9] :

$$G = 0.005 \cdot D \cdot B \quad [\text{grams}] \quad (2.43)$$

where :

G = weight of grease, gm

D, B = outside diameter and width of bearing, mm

2.5.2 Oil Lubrication

Oil lubrication is generally used when,

1. High speed and temperature prohibit the use of grease,
2. It is necessary to transfer frictional or applied heat away from bearing,
3. Adjacent machine parts are oil lubricated.

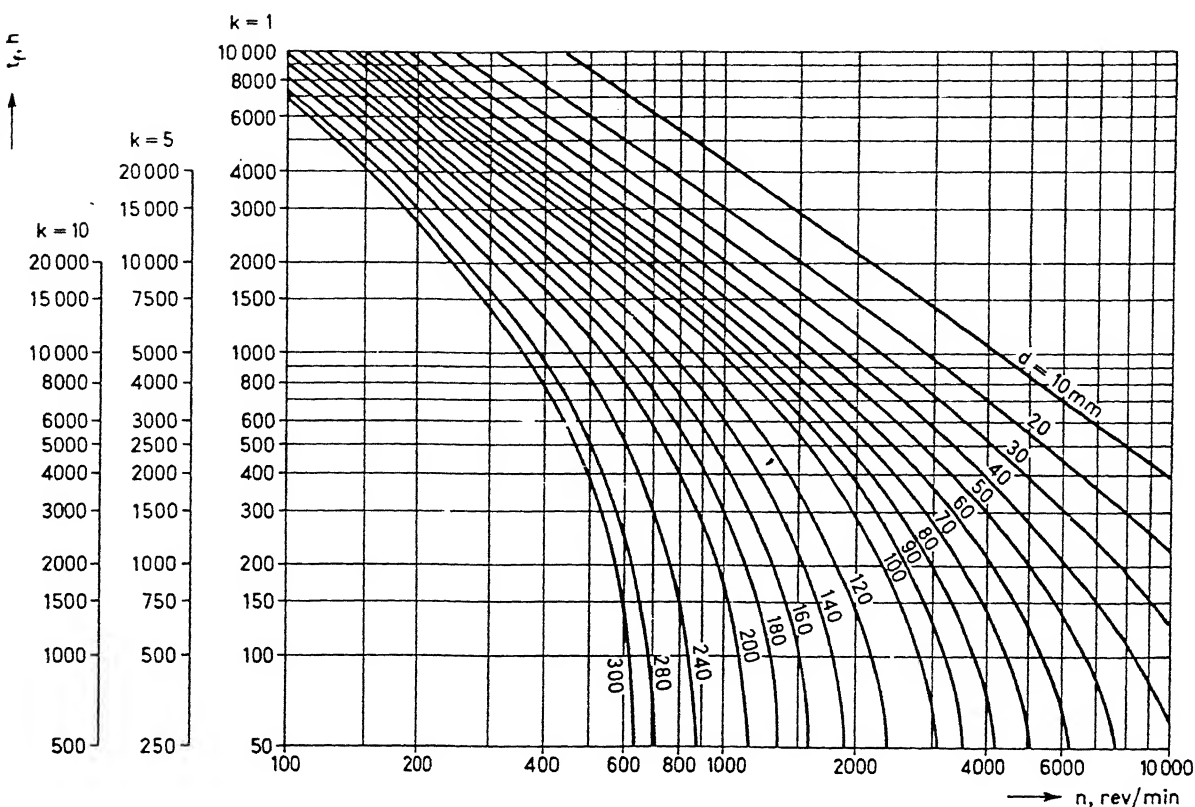


Figure 2.4: Relubrication interval [9]

Only solvent refined mineral oils with high or medium viscosity index (HVI or MVI) are generally used. Oils containing additives are normally required for exceptional operating conditions e.g. appreciable sliding in case of taper or spherical roller bearings, operating under heavy or shock load etc.

Selection

Viscosity is the most important criteria for selection of lubricant oil. In order to ensure a sufficient thick film of oil to be formed in the contact area, the oil must retain a minimum viscosity at the operating temperature (see Table 2.14). The suitable oil viscosity can be selected by considering the bearing size, speed and operating temperature from the nomogram shown in Fig.2.5. In nomogram, initially for the given speed (n), bearing bore diameter (d) and operating temperature (T), the required viscosity ν_1 is obtained. Since the viscosity varies with temperature and lubricating oils are commercially available with

viscosities specified at a particular temperature (say 50°C), finally the required viscosity ν at that temperature (50°C) is selected.

Bearing application	Operating temperature $^{\circ}\text{C}$	Bearing application	Operating temperature $^{\circ}\text{C}$
Cutter shaft of planing machine	40	Face grinding machine	55
Bench drill spindle	40	Jaw crusher	60
Horizontal boring spindle	40	Axleboxes of locomotives and passenger coaches	60
Circular saw shaft	40	Hammer mill	60
Blooming and slabbing mill	45	Wire mill	65
Lathe spindle	50	Vibratory motor	70
Vertical turret lathe	50	Rope stranding machine	70
Double-crank saw frame	50	Vibrating screen	80
Wood cutter spindle	50	Impact mill	80
Calender roll of a paper making machine	55	Ship's propeller thrust block	80
Backup rolls of hot strip mills	55	Vibrating road roller	90

Table 2.14: Operating temperatures of bearings in different machines [14]

However, it is very difficult to estimate required oil viscosity for a bearing application through computer programs or mathematical calculations by using nomogram and moreover no mathematical model or any method other than the nomogram is available in the literature so far. In nomogram the values are experience based and all scales used are neither linear nor interrelated logically, making it further difficult to develop any mathematical model. For this a mathematical model is developed and various steps involved in developement and, results compared with the values obtained from nomogram are described in the following section

1. For every constant value of speed (n) [rev/min] the relation between bearing bore diameter (d) and required viscosity ν_1 at operating temperature (T) were analysed and among all mathematical forms, the following equations using power law were found best suitable.

$$\begin{aligned}
 \nu_1 &= (d)^{-0.426728} \cdot 225.502 & \text{for } n = 300 \\
 &= (d)^{-0.359295} \cdot 108.938 & \text{for } n = 500 \\
 &= (d)^{-0.324920} \cdot 60.6023 & \text{for } n = 1000 \\
 &= (d)^{-0.290315} \cdot 41.4877 & \text{for } n = 1500 \\
 &= (d)^{-0.286292} \cdot 28.6498 & \text{for } n = 3000
 \end{aligned} \tag{2.44}$$

2. All above equations are represented by a general equation :

$$\nu_1 = d^{-\eta} \cdot \zeta_1 \tag{2.45}$$

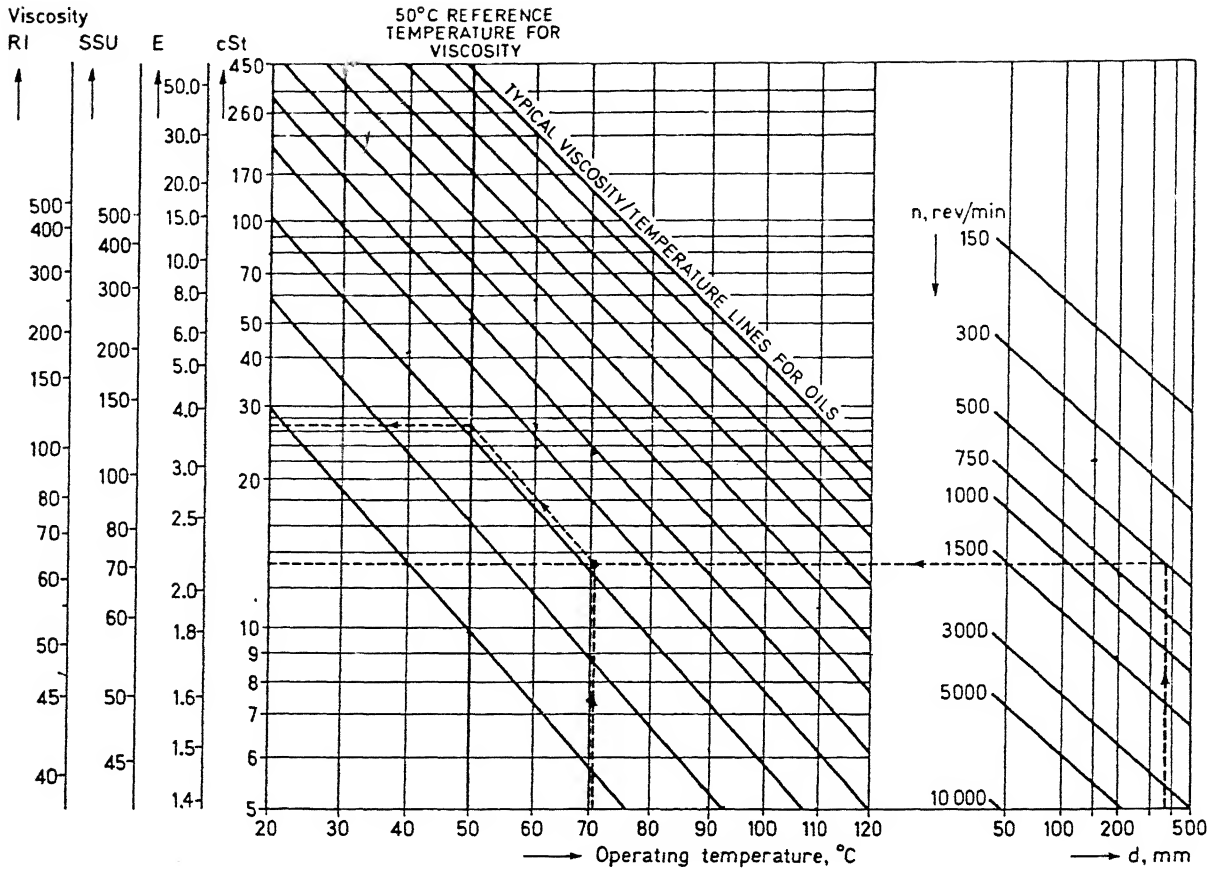


Figure 2.5: Nomogram to select oil viscosity [8]

where, ζ_1 and η_1 are the constants for a particular RPM value (n). Relation between RPM values and constants ζ_1 and η_1 were found and are as follows :

$$\zeta_1 = (n)^{-0.888114} \cdot 30448 \quad (2.46)$$

$$\eta_1 = (n)^{-0.174964} \cdot 1.10223 \quad (2.47)$$

3. For every constant value of ν_1 , the relation between required viscosity ν at 50 °C and operating temperature, T , were analysed and the general equation representing all the equations found suitable using exponential form is as follows :

$$\nu = \Phi \cdot \exp(\eta_2 T) \cdot \zeta_2 \quad (2.48)$$

where, ζ_2 and η_2 are constants for a particular value of ν_1 (Table 2.15) and Φ is a modification factor to take into account the variation in viscosity requirements in different RPM

ranges. Its values are as follows :

$$\begin{aligned}
 \Phi &= 1.30 && \text{for } n \leq 200 \\
 &= 1.13 && \text{for } 200 < n \leq 350 \\
 &= 1.00 && \text{for } n > 350
 \end{aligned} \tag{2.49}$$

4. Relations between ν_1 and constants ζ_2 and η_2 were found and are as follows :

ν_1 (cst)	η_2	ζ_2
6	0.030953	1.25114
8	0.033160	1.49269
10	0.035621	1.6304
20	0.043424	2.1595
40	0.048751	3.40775
70	0.051191	5.53141

Table 2.15: Values of constants ζ_2 and η_2

$$\zeta_2 = 0.008737 \cdot \ln(\nu_1) + 0.015520 \tag{2.50}$$

$$\eta_2 = 0.065234 \cdot \nu_1 + 0.904462 \tag{2.51}$$

The procedure to be used to calculate the required viscosity ν is as follows :

- Calculate constants ζ_1 and η_1 for given speed(n) using equations 2.46 and 2.47 .
- Calculate ν_1 for given bearing bore diameter d from equation 2.45 .
- Calculate constants ζ_2 and η_2 for obtained value of (ν_1) using equations 2.50 and 2.51.
- Finally calculate ν for given operating temperature T from equation 2.48.

The results obtained for different values of speed, bore diameter and operating temperature are compared with nomogram values and found quite in agreement (shown in Table 2.16).

2.6 Selection of Shaft and Housing Fits and Tolerances

To prevent the damage of the bearings and associated components it is important to maintain correct fits between the bearings and seatings. The most important factors which are considered while selecting bearing fits are as follows :

Speed (n)	Bore dia. (d)	Oper. temp. (T)	Viscosity (cst)			
			Calculated		Nomogram	
			(ν_1)	(ν)	(ν_1)	(ν)
150	50	50	76.83	76.83	80	80
150	100	60	55.91	87.91	58	90
150	200	80	40.68	147.1	41	170
300	50	80	44.29	175.87	44	180
300	200	70	25.22	52.81	24.5	53
300	500	120	17.38	243.72	17	255
500	100	50	22.05	22.05	21	21
500	150	70	18.97	38.93	18	38
750	200	90	13.61	56.42	13.2	57
1000	50	60	18.20	24.29	17.5	25
1000	150	50	12.68	12.68	12.2	12.2
1000	300	90	10.09	38.89	11	42
1500	100	110	11.21	92.03	11	90
3000	100	70	7.12	13.47	7.4	13.8
5000	150	80	4.55	11.91	5.0	11

Table 2.16: Comparison of calculated and nomogram values of ν and ν_1

Conditions of rotation : It refers to direction of load in relation to the bearing rings. In case of rotating load (load moving relative to the bearing ring) an interference fit is used to prevent creep of load on its seating causing wear (fretting corrosion) of the contacting surfaces whereas, in case of stationary load (load is stationary relative to the ring) an interference fit is not necessary unless dictated by other requirements. When the direction of the load is indeterminate, it is desirable that both rings have interference fit.

Magnitude of load : The load on bearing inner ring causes it to expand resulting in an easing of fit on the seating hence heavier the load, the greater is the interference required.

Displacement of a non locating bearing : When a non-separable bearing is used at the non-locating position, it is necessary that under all conditions of operation one of the rings is free to move axially and is ensured by using a clearance fit.

Other factors : In addition to factors mentioned above, internal clearance, temperature conditions, requirements regarding running accuracy, design and material of shaft and housing and ease of mounting and dismounting are also considered. The summarised information for selection of shaft and housing fits is shown in Tables 2.17 to 2.21 . According to the type of fit the bearing bore and outside diameter tolerances alongwith shaft diameter and housing bore tolerances are obtained from standard tolerance tables(ISO :BS 4500).

Design and Operating Conditions			Ball Bearings				Cylindrical Roller Bearings				Spherical Roller Bearings				Tolerance Classification												
			Basic Bearing Bore																								
Rotational Conditions	Radial Loading		mm		in.		mm		in.		mm		in.														
			Over	Incl.	Over	Incl.	Over	Incl.	Over	Incl.	Over	Incl.	Over	Incl.													
Inner ring rotating in relation to load direction or	Light radial load		0 18	18 All	0 0.71	0.71 All	0 40 140	40 140 320	0 1.57 5.52	1.57 5.52 12.6	0 40 100	40 100 200	0 1.57 3.94	1.57 3.94 7.88	h5 j6 ^c k6 ^c m6 ^c												
	Normal radial load		0 18	18 All	0 0.71	0.71 All	0 40 100 140	40 100 140 320	0 1.57 3.94 5.52	1.57 3.94 5.52 12.6	0 40 65 100 140 280 500	40 65 100 140 280 All	0 1.57 2.56 3.94 5.52 11.1 19.7	1.97 2.56 3.94 5.52 11.1 19.7 All	j5 k5 m5 m6 n6 p6 r6 r7												
Load direction is indeterminate			18 100		100 All		0.71 3.94		3.94 All		0 40 65 140		40 65 140 320		0 1.57 2.56 5.52		1.57 2.56 5.52 12.6		0 40 65 100 140 200		40 65 100 140 200 All		0 1.57 2.56 3.94 5.52 7.88		1.57 2.56 3.94 5.52 7.88 All		k5 m5 m6 n6 p6 r6 r7
Inner ring stationary in relation to load direction	All loads	Inner ring must be easily axially displaceable	All sizes												g6												
		Inner ring need not be easily axially displaceable	All sizes												h6												
Pure thrust (axial) load			All sizes												j6												

Table 2.17: Fits for shafts for radial bearings [15]

Thrust bearings			Shaft	
Type of load	Bearing type	Shaft diameter	Operating conditions	Tolerance field
Axial load	Thrust ball bearings	All sizes		j6
	Thrust ball bearings double-acting	All sizes		k6
	Cylindrical roller thrust bearings or thrust needle roller and cage assemblies with shaft washer	All sizes		h6 (j6)
	Thrust cylindrical roller and cage assemblies or thrust needle roller and cage assemblies with track or thrust washer	All sizes		h10
	Thrust cylindrical roller and cage assemblies or thrust needle roller and cage assemblies	All sizes		h8
Combined load	Spherical roller thrust bearings	All sizes	Point load on shaft washer	j6
		up to 200 mm	Circumferential load on shaft washer	j6 (k6)
		over 200 mm		k6 (m6)

Table 2.18: Fits for shafts for thrust bearings [14]

Design and Operating Conditions				Tolerance Classification
Rotational Conditions	Loading	Outer Ring Axial Displacement Limitations	Other Conditions	
Outer ring stationary in relation to load direction	Light, normal, and heavy	Outer ring must be easily axially displaceable	Heat input through shaft	G7
			Housing split axially	H7
			Housing not split axially	H6 ^c
	Shock with temporary complete unloading	Outer ring need not be axially displaceable		J6 ^c
Load direction is indeterminate	Light and normal		Split housing not recommended	K6 ^c
	Normal and heavy			M6 ^c
	Heavy shock			N6 ^c
Outer ring rotating in relation to load direction	Light		Thin wall housing not split	P6 ^c
	Normal and heavy			
	Heavy			

Table 2.19: Fits for housings for radial bearings [15]

Thrust bearings			Housing
Type of load	Bearing type	Operating conditions	Tolerance field
Axial load	Thrust ball bearings	Standard running accuracy	E8
		High running accuracy	H6
	Cylindrical roller thrust bearings or thrust needle roller and cage assemblies with housing washer		H7 (K7)
	Thrust cylinder roller and cage assemblies or thrust needle roller and cage assemblies with track or thrust washer		H11
	Thrust cylindrical roller and cage assemblies or thrust needle roller and cage assemblies		H10
	Spherical roller thrust bearings	Normal load High load	E8 G7
Combined load point on housing washer	Spherical roller thrust bearings		H7
Combined load circumferential load on housing washer	Spherical roller thrust bearings		K7

Table 2.20: Fits for housings for thrust bearings [14]

2.7 Selection of Sealing Methods

Bearings must be protected by suitable seals against the entry of moisture, dirt and other contaminants and to prevent the loss of lubricant. Many factors are considered when deciding the best sealing arrangement for a given bearing application e.g. type of lubricant, peripheral speed at the sealing surface, misalignment of the shaft, available space, friction, temperature rise and cost. Bearings having integral seals or shields may also be used for saving space.

Seal Type	Suitability										Specific Characteristics
	Lubrication oil	Lubrication grease	Speed	Temperature	Dirt	Moisture	Installation	Cost	Space Req.		
<i>Non Rubbing seals</i>											
Simple gap	No	Yes	High	High	No	No	Easy	Low	Mod.	For horizontal shafts	
grooved Labyrinth	No	Yes	High	High	Low	Low	Mod.	Mod.	Mod.		
Labyrinth with spiral groove	Yes	Yes	High	High	Low	Low	Mod.	High	Mod.		
Labyrinth with Radial Webs	No	Yes	High	High	Mod.	Low	Mod.	Mod.	Mod.	For split housing	
Labyrinth with Axial Webs	No	Yes	High	High	Mod.	Low	Mod.	Mod.	Mod.	For solid housing	
Labyrinth with Inclined Webs	No	Yes	High	High	Mod.	Low	Mod.	Mod.	Mod.	Self aligning bear.	
ready to mount Labyrinth unit	No	Yes	High	High	Mod.	Low	Easy	Mod.	Mod.		
Labyrinth with Piston rings	Yes	Yes	High	High	Mod.	Low	Mod.	Mod.	Low	For horizontal shafts	
Oil groove rings	Yes	Yes	High	High	Mod.	Low	Mod.	Mod.	Mod.		
Flinger rings	Yes	No	High	High	Mod.	Low	Mod.	Mod.	Mod.		
<i>Rubbing seals</i>											
Felt	No	Yes	Low	Low	Mod.	Low	Mod.	Low	Mod.	Deep groove ball bear.	
Asbestos graphite lip	No	Yes	Low	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.		
V ring	Yes	Yes	Low	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.		
Spring steel seals	No	Yes	High	High	Mod.	High	Mod.	Mod.	Mod.		
<i>Combined seals</i>	Yes	Yes	High	High	High	High	Mod.	High	High		

Table 2.21: Seals for different bearing applications [10,14]

Chapter 3

System Design and Implementation

The present chapter describes the design and implementation of the proposed bearing selection system named **BEARSEL**. After requesting for the minimum essential input data from the user, BEARSEL is capable of selecting the best fit bearing for a specific problem and also advising the user on the installation (lubrication, sealing etc) of the bearing. To make the system responsive to dynamic information, the facility of updating database has been incorporated. Further, in addition to displaying inputs and outputs on the screen at various stages of the system run, on line printing option is included to get hardcopies. The expense on the stack memory is compensated by the near 100 % menu contact with the user.

The system is interactive, menu driven and user friendly. It is implemented using DBase IV.2 on an IBM compatible PC-XT/AT.

3.1 Menu Structure

Based on the system flow chart (Fig. 2.3), BEARSEL is designed and implemented in six modules as follows :

- Data-Input/Edit
- Bearing Selection
- Installation of Bearings
- Update
- Print
- Exit

It is presented by a menu structure shown in Fig.3.1. Each option of the top horizontal (main) menu refers to one module, which further leads to sub-menus and sub-sub-menus. Menus which appear in sequence depend on previous selections. Only relevant alternatives

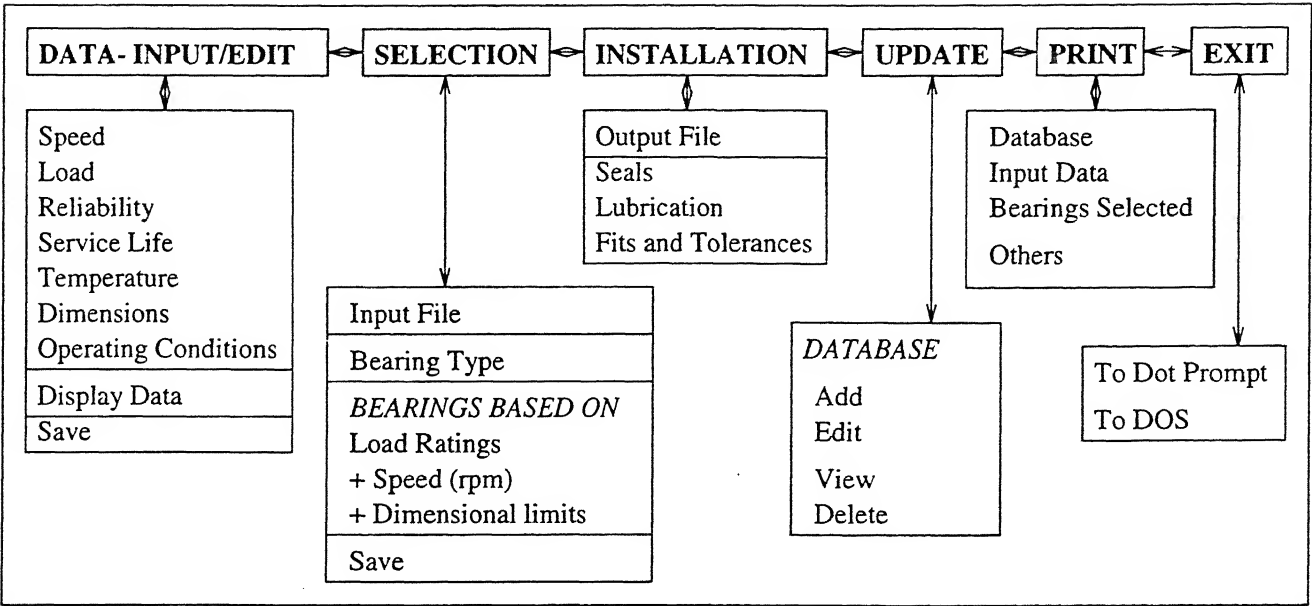


Figure 3.1: Menu structure of the BEARSEL

are presented in each new menu. The hierarchical and chain, hybrid menu structures can be easily traversed with the help of cursor keys and selection of option is made by pressing return key. Although all the modules are interlinked and users have easy access to any menu or sub-menu option from any current position, a certain order is necessary to be followed while inputting data or selecting bearings. Screen printouts for all modules are shown in Appendix A.

3.2 Input to the System (DATA-INPUT/EDIT)

This is the initial and independent module with which the user interacts to give necessary inputs. The remaining modules are dependent upon the knowledge base and inputs acquired by this module. The system provides various alternatives for each type of input from which the user is expected to select and enter the data in both qualitative as well as quantitative forms. Essentially, all the input information should be entered to get good results from the system. The flow chart of implementation procedure for this module is shown in Fig 3.4. The various inputs required with the order in which they are to be entered are as follows:

3.2.1 Speed

The system displays two options, **Constant** and **Variable** to enter speed data. For constant speed, user has to enter speed value (rpm) whereas, in case of variable, number of steps of speed cycle, speed values and percentage of cycle/total time for all steps are to be entered. Mean speed is then calculated by the system (Eqn. 2.27).

3.2.2 Load

The load data are entered by selection from a series of menus which is implemented as follows :

1. Selection of load type (Radial, Thrust and Sudden) one by one.
2. Selection of magnitude (Negligible, Constant or Variable) for radial and thrust load types followed by selection of nature (Step, Fluctuating, Stationary cum Rotary or Other forms), if magnitude is variable.

For sudden load selection is done from type of shock (Negligible, Light, Medium or Heavy). System provides help to the user in selection by displaying type of shock for various applications (Table 2.12).

3. Enter values of required load parameters depending on type, magnitude and nature of load (see Table 3.1).
4. Selection of load direction (Constant, Rotating or Indeterminate for radial load, and Single or Double acting for thrust load).
5. Calculation of Mean loads for radial and thrust load types (if magnitude is variable) and shock factor FS . References of equations and tables involved are mentioned in Table 3.1.
6. Finally return to main input menu with Exit option

A screen printout is shown in Fig. 3.2 which shows how load data are entered. The user has selected the * marked choices for a variable radial load of step nature and has entered appropriate values.

3.2.3 Reliability

Here, user is asked to enter reliability if desired more than 90 % (Range 90–99 %). System then calculates life adjustment factor, a_1 (Table 2.7).

Table 3.1: Implementation details of Load Input Data

Enter the % of cycle/total time for this load step

Figure 3.2: Screen printout of Load Input

3.2.4 Service Life

For the convenience of the user, system provides two alternatives to enter bearing service life (Requisite basic rating life) data.

1. For general bearing applications requisite life may be entered in terms of operating hours.
2. For rail/road applications life data may be entered in millions of kilometers with wheel diameter in meters.

Help is provided to assist the user in determining requisite life for various applications (Tables 2.8 and 2.9)

3.2.5 Temperature

Here, expected maximum and minimum bearing temperature in $^{\circ}C$ are to be entered. Depending on maximum temperature system calculates temperature factor FT (Table 2.10).

3.2.6 Dimensions

Dimensional constraints to be satisfied by the bearing are to be entered in terms of maximum and minimum bearing bore diameter, outer diameter and width in mm.

3.2.7 Operating Conditions

A special care is required while inputting operating conditions. Several operating conditions are displayed (shown in Fig.3.3) and user has to select desired level for each of them from the following options :

- Critical
- Important
- Usual
- Undesirable

Depending on desired level selected, each of the operating conditions is assigned a weighted factor which is used to identify suitable bearing types and then grading (ranking) them. The option 'critical' should only be selected when it is extremely demanding by the application because otherwise the system will eliminate all those bearing types which are not critically suitable for that operating condition. For example, running quietness is critical for the bearings of electric motors used in hospitals, offices or homes but not for those, used in industries.

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT								
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Data ----- Save B E A R E S ■ A E R S E L	PLEASE ENTER THE DESIRED LEVEL FOR ALL OPERATING CONDITIONS _____ <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border-bottom: 1px solid black; text-align: center;">OPERATING CONDITIONS</td> <td style="width: 50%; border-bottom: 1px solid black; text-align: center;">DESIRED LEVEL</td> </tr> <tr> <td style="border: 1px solid black; padding: 5px; vertical-align: top;"> Running Accuracy Self Alignment Capability Radial Rigidity Axial Rigidity Running Quietness Low Friction Maintenance Cost EXIT TO MAIN MENU </td> <td style="border: 1px solid black; padding: 5px; vertical-align: top; text-align: center;"> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td>Critical</td></tr> <tr><td>Important</td></tr> <tr><td>Usual</td></tr> <tr><td>Undesirable</td></tr> </table> </td> </tr> </table>					OPERATING CONDITIONS	DESIRED LEVEL	Running Accuracy Self Alignment Capability Radial Rigidity Axial Rigidity Running Quietness Low Friction Maintenance Cost EXIT TO MAIN MENU	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td>Critical</td></tr> <tr><td>Important</td></tr> <tr><td>Usual</td></tr> <tr><td>Undesirable</td></tr> </table>	Critical	Important	Usual	Undesirable
OPERATING CONDITIONS	DESIRED LEVEL												
Running Accuracy Self Alignment Capability Radial Rigidity Axial Rigidity Running Quietness Low Friction Maintenance Cost EXIT TO MAIN MENU	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td>Critical</td></tr> <tr><td>Important</td></tr> <tr><td>Usual</td></tr> <tr><td>Undesirable</td></tr> </table>	Critical	Important	Usual	Undesirable								
Critical													
Important													
Usual													
Undesirable													
Select desired level of OPERATING CONDITION and press < Enter >													

Figure 3.3: Screen printout of Operating Conditions Input

In addition to these inputs, **Display Data** and **Save** options have also been provided to facilitate the user to view and check the inputs and then save them for future requirements.

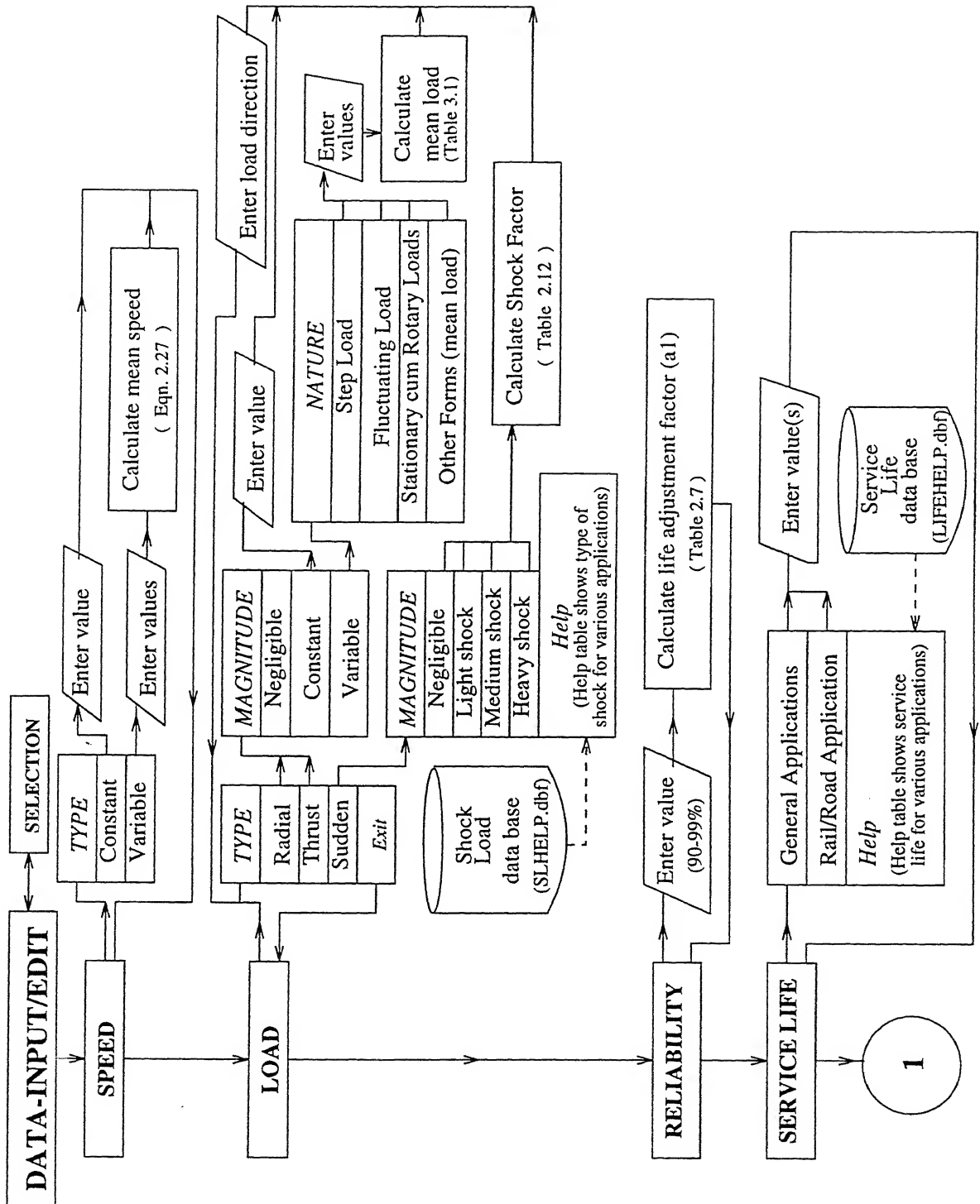


Figure 3.4: Flow chart: Implementation Procedure of DATA-INPUT/EDIT module

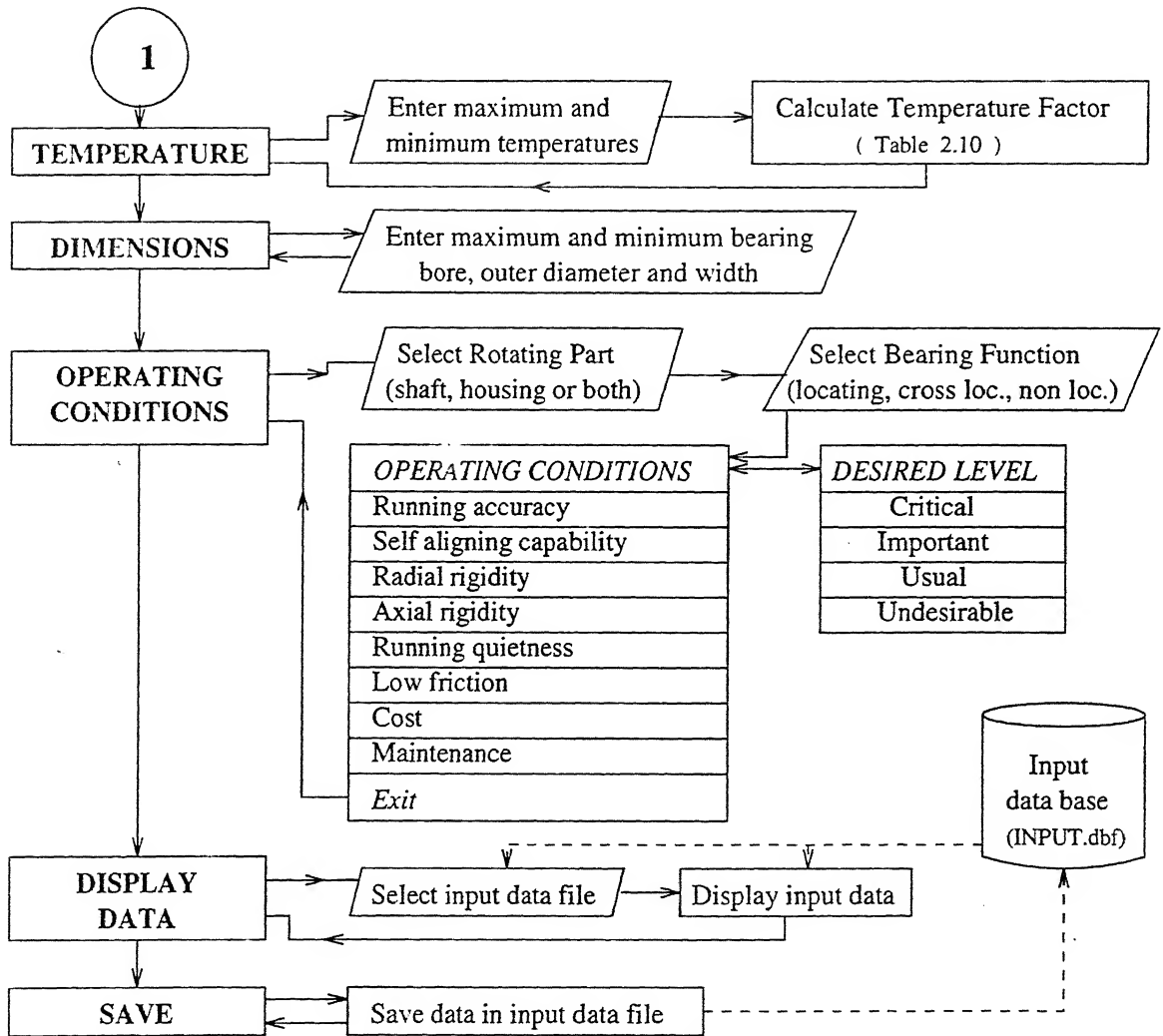


Figure 3.4: (contd ...)

3.3 Selection of Bearings (SELECTION)

It is a decision making module of BEARSEL, and may be called as the "crux" of the system. First of all the user has to select the input file to retrieve relevant application (input) data, acquired in data input module, for which bearings are to be selected. Based on input and characteristics of various bearing types (discussed in Section 2.3), this module identifies and ranks the suitable bearing types which are displayed for the user in the order of preference. Out of the displayed alternatives, the user has to select one depending upon the preference, economic considerations, availability and design constraints. Finally the system selects the bearings of appropriate size by pruning of alternatives (bearings) available within that bearing type. Selected bearings are then displayed for the user and saved in an output file for future use. The flow chart of implementation procedure is shown in Fig. 3.7 .

3.3.1 Selection of Bearing Types

Here the system works exactly in the same manner as an expert does. It first lists all the possible bearing types using a knowledge-base and a set of rules which describe the suitability, unsuitability and relative suitability of all bearing types for each of the design attributes, operating conditions and relevant parameters (Tables 2.1–2.4). Then by elimination process it tests the suitability of all possible alternatives for the pertinent attributes and operating conditions (specified for that application), one at a time, to eliminate unsuitable bearing types. For example, if the required bearing function is "Locating" then bearing types as, cylindrical roller bearings (type N, NU) and bearings having filling slots can not be used, which are then eliminated from the list of suitable candidates. It is implemented as follows :

1. Sorting of bearing types based on maximum speed available with that bearing type (Table 2.1).
2. Sorting of bearing types based on loading conditions. (Depending on whether, bearing is to carry only radial load, only thrust load or combined load, bearing types capable of carrying that load are sorted (see Table 2.1)). Further depending on particular loading condition, sorting is done based on,
 - Admissible load ratio F_a/F_r for combined loads (Table 2.1).
 - Thrust load direction for only thrust load (capability of bearing type to carry thrust load in single or double direction is checked)(Table 2.1)
 - Bearing function for only radial and combined loads (locating capability is checked)(Table 2.1).
3. One by one Sorting of bearing types based on desired level for each of the operating conditions (Table 2.3). Here, for any critical operating condition, the bearing types not having excellent or good suitability are eliminated from the list of possible candidates.

3.3.2 Ranking of Suitable Bearing Types

After identification of certain suitable types of bearing, the evaluation of the relative suitability of these bearing types is carried out by grading (ranking) them on the basis of weighted factor method. The procedure adopted is as follows :

- All bearing types have different degree of capability and suitability (Tables 2.1 and 2.3) relative to each other for a particular attribute (load carrying ability, locating ability etc.) or operating condition. Depending on degree of suitability/capability each bearing type is assigned a numeric value as follows:

Degree of suitability/capability	Value
Excellent	4
Good	3
Fair	2
Poor	1
Unsuitable	0

- A suitability matrix is generated whose rows are represented by suitable bearing types and columns by pertinent attributes (radial load capacity in case of when only radial load is acting etc.) and operating conditions. Each element of matrix represents relative suitability of corresponding bearing type (row) with respect to that particular attribute/operating condition (column).
- Based on input data, weighted factors for each of the attribute and operating condition are determined. For example, an operating condition having critical or important as desired level, is assigned higher weighted factor (priority) than to a condition having usual as desired level.
- Now, columns of suitability matrix are multiplied by corresponding weighted factors to introduce the relative priority of different attributes and operating conditions for that particular application.
- Finally elements of each row of suitability matrix are summed up. The resulting value (weighted value) for each bearing type indicates the relative suitability for the entered inputs. Higher is the weighted value, higher is the preference. The selected bearing types in order of preference are then displayed and stored with input data in a temporary database.

The Fig.3.5 shows a screen printout of selected bearing types in the order of preference.

3.3.3 Selection of Optimum Sized Bearings

Initially the user is asked to select one bearing type out of the sorted list of suitable bearing types (based on preference, cost, availability and other factors). Accordingly the

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT												
<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> Input File <hr/> Bearing Type <hr/> BEARINGS BASED ON Load Ratings + Speed (rpm) + Dimensional limits <hr/> Save </div> <div style="display: flex; align-items: center;"> <div style="text-align: center; margin-right: 10px;"> B E A R E S A E R S E L </div> <div style="width: 20px; height: 20px; background-color: black; border: 1px solid black;"></div> </div>	<div style="border: 1px solid black; padding: 10px;"> <p style="text-align: center; margin: 0;">SUITABLE BEARING TYPES</p> <hr style="border: 1px solid black; margin: 5px 0;"/> <table border="1" style="width: 100%; border-collapse: collapse; margin: 5px 0;"> <thead> <tr> <th style="text-align: left; padding: 5px;">BEARNAME</th> <th style="text-align: left; padding: 5px;">DBNAME</th> <th style="text-align: left; padding: 5px;">WEIGHTAGE</th> </tr> </thead> <tbody> <tr> <td style="padding: 5px;">ANGULAR CONT.BALL(2)</td> <td style="padding: 5px;">ACBB2</td> <td style="padding: 5px; text-align: right;">58</td> </tr> <tr> <td style="padding: 5px;">ANGULAR CONT.BALL(3)</td> <td style="padding: 5px;">ACBB3</td> <td style="padding: 5px; text-align: right;">58</td> </tr> <tr> <td style="padding: 5px;">DEEP GROOVE BALL(1)</td> <td style="padding: 5px;">DGBB1</td> <td style="padding: 5px; text-align: right;">57</td> </tr> </tbody> </table> <p style="text-align: center; margin: 5px 0;">(More weightage value indicates higher priority)</p> <p style="text-align: center; margin: 0;">PLEASE SELECT ONE BEARING TYPE</p> </div>					BEARNAME	DBNAME	WEIGHTAGE	ANGULAR CONT.BALL(2)	ACBB2	58	ANGULAR CONT.BALL(3)	ACBB3	58	DEEP GROOVE BALL(1)	DGBB1	57
BEARNAME	DBNAME	WEIGHTAGE															
ANGULAR CONT.BALL(2)	ACBB2	58															
ANGULAR CONT.BALL(3)	ACBB3	58															
DEEP GROOVE BALL(1)	DGBB1	57															

keys and PRESS <Esc>

Figure 3.5: Screen printout of suitable bearing types

system retrieves the relevant bearing database and input data. For all bearing types, separate databases have been generated which store the relevant information and values of pertinent attributes (boundary dimensions, basic load ratings, limiting speeds, load factors, mass etc.) of all bearings which are available from different manufacturers.

The final selection is achieved in three stages as follows :

Selection of Bearings based on Load Ratings

Initially using input data and data available in bearing database (of selected bearing type), for each bearing, equivalent dynamic load, P , and equivalent static load, P_o , are calculated (Equations 2.26 and 2.11; Tables 2.5 and 2.11). Then required dynamic load rating, C_{req} , is calculated (Eqn. 2.33) and compared with basic dynamic load rating, C (specified for each bearing in bearing database). If C is found greater than to C_{req} , the bearing is further checked for safe index of static stressing (Eqn. 2.12; Table 2.6) and is stored in a temporary database, otherwise it is dropped (not copied to temporary database of suitable bearings). Same process continues until whole database is not scanned. Sorted data (selected bearings based on load ratings) are then displayed for the user. If no bearing is found suitable at any stage, user is suggested to select another bearing type.

Selection of Bearings based on Limiting Speed (RPM)

Here the bearing data base, which has already been sorted for load ratings, is further scanned to sort the bearings satisfying the condition of required speed (input data) is lower than limiting speeds (specified in bearing database for each bearing). All suitable

bearings are displayed and stored into a temporary database.

Selection of Bearings based on Dimensional Constraints

Sorted database obtained from previous stage is further scanned and sorted for bearings satisfying dimensional constraints (maximum and minimum bearing, bore diameter, outer diameter and width). Finally selected bearings are then displayed for the user and are saved in an output database.

The screen printout of the finally selected bearings is shown in Fig.3.6 and flow chart of implementation procedure for this module is shown in Fig. 3.7.

FINALLY SELECTED SUITABLE BEARINGS									
B_NUMBER	COMPANY	BORE_DIA	OUTER_DIA	WIDTH	C	CO	RPM_OIL	RPM_GRES	M
7314BG	SKF	70	150	70	143000	143000	3800	2800	
7315BG	SKF	75	160	74	153000	160000	3600	2600	
7316BG	SKF	80	170	78	166000	180000	3400	2400	
<div> <p> B_NUMBER : Bearing Number C : Dynamic Load Rating(Newtons) CO : Static Load Rating(Newtons) RPM_* : Limiting Speeds(rpm) MASS : Weight of bearing(g) Linear Dimensions are in m.m. </p> </div>									
<div> <p> PRESS [ESC] TO CONTINUE FURTHER </p> </div>									
<div> <p> Use keys to see all BEARINGS and SPECIFICATIONS </p> </div>									

Figure 3.6: Screen printout of finally selected bearings

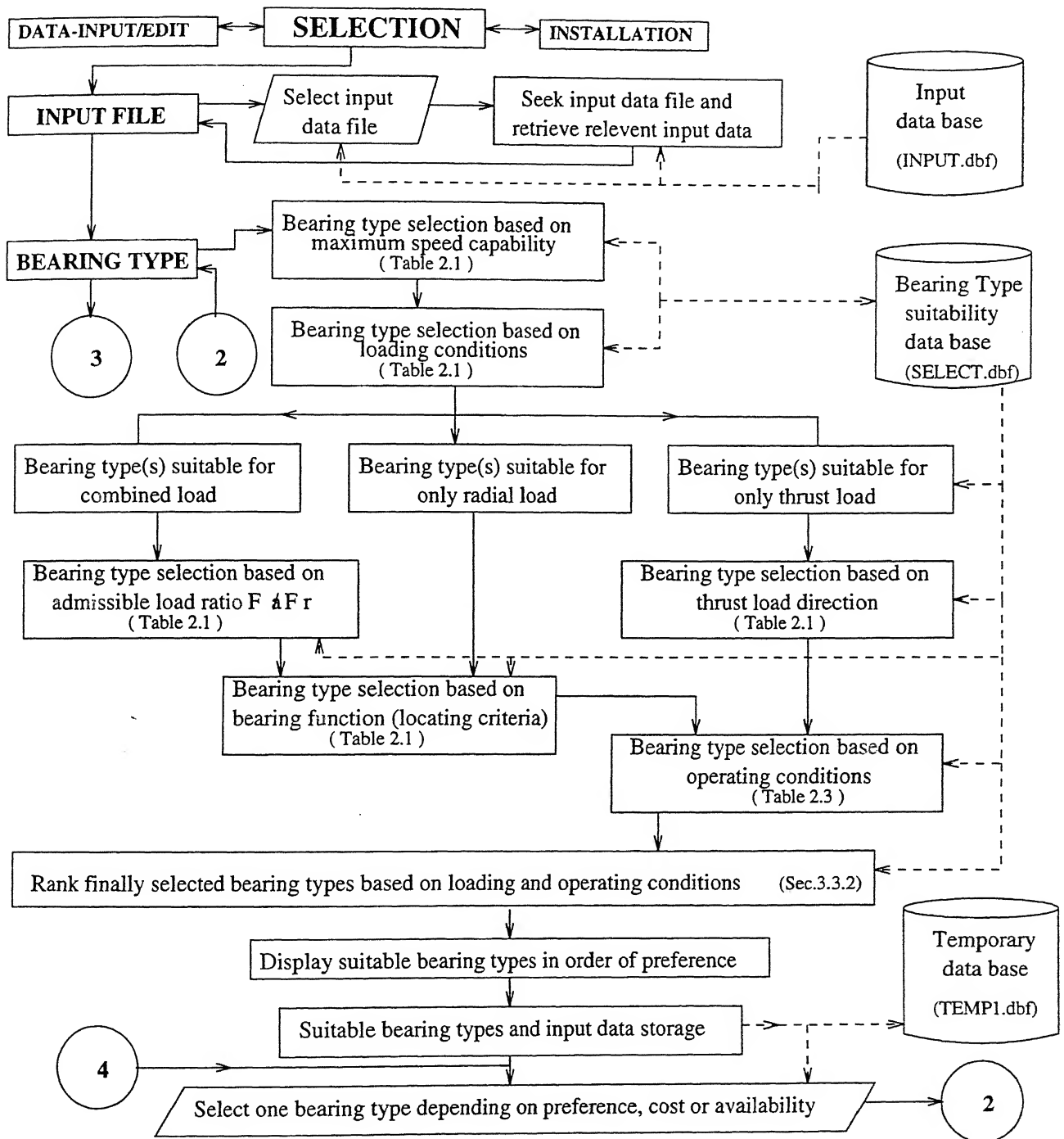


Figure 3.7: Flow chart: Implementation Procedure of SELECTION module

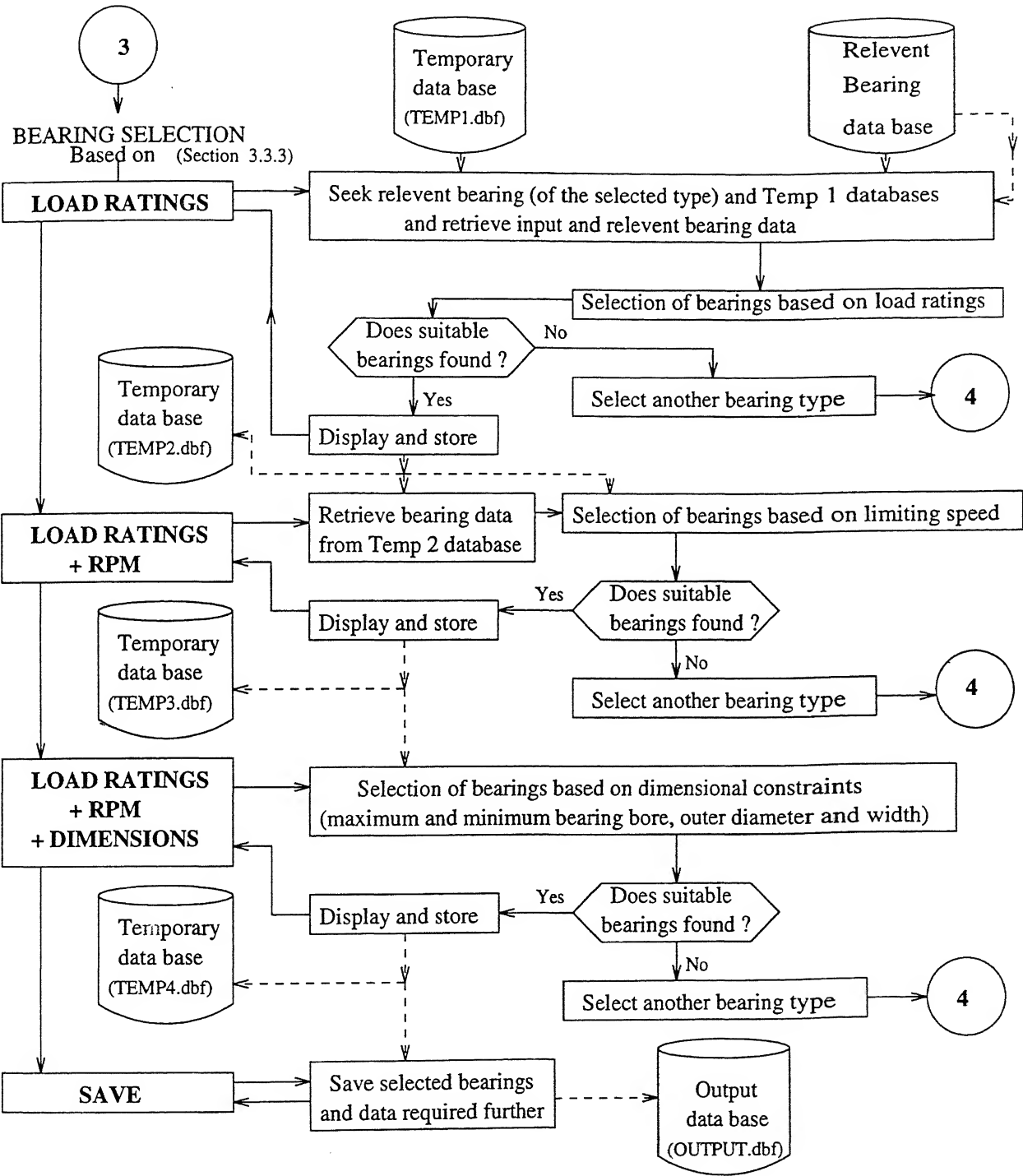


Figure 3.7: (contd ...)

3.4 Installation of Bearings (INSTALLATION)

In this module three major application areas of the bearing installation have been included about which the user is given advice. These are :

- Seals,
- Lubrication, and
- Fits and tolerances.

Initially the user is asked to select the output file (in which finally selected bearings have been saved), accordingly the system retrieves the relevant selected bearings with required data. Then user has to select one bearing for which advice on installation is sought. Recommendations are displayed for the application area (seals, lubrication etc.), selected by the user. The flow chart of implementation procedure is shown in Fig. 3.11 .

3.4.1 Selection of Sealing method

The database of selected bearing is scanned to check the availability of bearing with integral seals or shields (specified for each bearing in bearing database) and this information is displayed to the user. The system has one knowledge-base (Table 2.21) which gives advice for suitability of different seal types for a particular application on the user's request. Fig.3.8 shows the screen printout of the recommendations made.

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT										
<div style="border: 1px solid black; padding: 5px;"> Output File <hr style="border-top: 1px dashed black;"/> Seals Lubrication Fits & Tolerances </div> <div style="margin-top: 20px;"> B E A R E S A E R S E L </div>	SEALS & SHIELDS Bearing Number : 7314BG <div style="border: 1px solid black; padding: 10px; margin: 10px auto; width: 80%;"> <div style="text-align: center; border-bottom: 1px solid black; margin-bottom: 5px;">BEARING AVAILABILITY</div> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">WITH (Integral)</th> <th style="text-align: left;">STATUS</th> </tr> </thead> <tbody> <tr> <td>SINGLE SEAL</td> <td>No</td> </tr> <tr> <td>DOUBLE SEALS</td> <td>No</td> </tr> <tr> <td>SINGLE SHIELD</td> <td>No</td> </tr> <tr> <td>DOUBLE SHIELDS</td> <td>No</td> </tr> </tbody> </table> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> NOTE : To select SEALS for UNSEALED BEARINGS PRESS key F2 </div> <div style="text-align: center; margin-top: 10px;"> press any key to continue </div> </div>					WITH (Integral)	STATUS	SINGLE SEAL	No	DOUBLE SEALS	No	SINGLE SHIELD	No	DOUBLE SHIELDS	No
WITH (Integral)	STATUS														
SINGLE SEAL	No														
DOUBLE SEALS	No														
SINGLE SHIELD	No														
DOUBLE SHIELDS	No														

Recommendations for bearing INSTALLATION

Figure 3.8: Screen printout of Seal recommendations

3.4.2 Selection of Lubrication Method

The system has one rule set and knowledge base (Table 2.13) which is used to decide which lubrication method (oil or grease) should be used for given conditions (Section 2.5). For grease lubrication a second rule set and a knowledge base is used to recommend the grease type and its consistency (NLGI grade) etc (Section 2.5.1). Afterwards using input data and knowledge, relubrication period and amount of grease required are determined (Eqns. 2.42 and 2.43). For oil lubrication the viscosity of oil is determined using the model described in Section 2.5.2 .

All the recommendations are displayed finally for the user. Fig. 3.9 shows screen printout of the lubrication recommendations.

3.4.3 Selection of ISO Fits and Tolerances

The system has one set of rules which represents general knowledge about applications and bearings. which is used to infer the rotating part (shaft, housing or both), rotating conditions on inner and outer bearing ring, and the type of fit (interference or clearance) to be used etc. A second rule set contains rules which are specialised at recommending ISO shaft, housing fits for a given bearing. This set uses values or knowledge that is inferred by the previous set. Both sets are performed with backward chaining inference (Section 2.6; Tables 2.17–2.20).

There is a third backward chaining rule set which is used to infer recommended tolerances for a given bearing fit type (Tolerance Tables, ISO :BS 4500). All the recommendations about the fit type, fits and tolerances for shaft and housing are displayed for the user. Fig.3.10 shows the screen print of such fits recommendations.

3.5 Update Database (UPDATE)

Rolling element bearings, being the most widely used mechanical components, have attracted continuous research in this field resulting in improvement in existing bearings and introduction of new bearings. To incorporate this dynamism this module has been designed and implemented by facilitating the user to update the bearing databases. Four options are provided as follows :

- Add
- Edit
- View
- Delete

Simillar to previous modules, the user has to select the bearing type first and accordingly the system retrieves the relevent bearing database. In add procedure, to avoid duplication, the pre existence of the bearing record is checked by scanning the database for bearing

DATA-INPUT/EDIT SELECTION INSTALLATION UPDATE PRINT EXIT

Output File

Seals
Lubrication
Fits & Tolerances

LUBRICATION DETAILS

Bearing Number : 7314BG

SPECIFICATIONS
LUBRICANT : Oil
VISCOSITY(cst) : 14.79
VISCOSTY INDEX : Medium OR High

ADVICE :For centralised oil lubrication system
same oil may also be used for the bearing

Press any key to continue

B E A R ■
E S
A E
R S E L

Recommendations for bearing INSTALLATION

DATA-INPUT/EDIT SELECTION INSTALLATION UPDATE PRINT EXIT

Output File

Seals
Lubrication
Fits & Tolerances

LUBRICATION DETAILS

Bearing Number : 7314BG

SPECIFICATIONS
LUBRICANT : GREASE
GREASE CODE : L-XG-271
QUANTITY REQD. (g) : 52.50
REGREASE PERIOD(Hrs): 13933.20
NLGI No : 2 OR 3

ADVICE :Fill grease upto 30-50 % of free space
Over packing may cause over heating

NOTE : For GREASE CODE description press F2
Press any key to continue

B E A R ■
E S
A E
R S E L

Recommendations for bearing INSTALLATION

Figure 3.9: Screen printouts of Lubrication recommendations

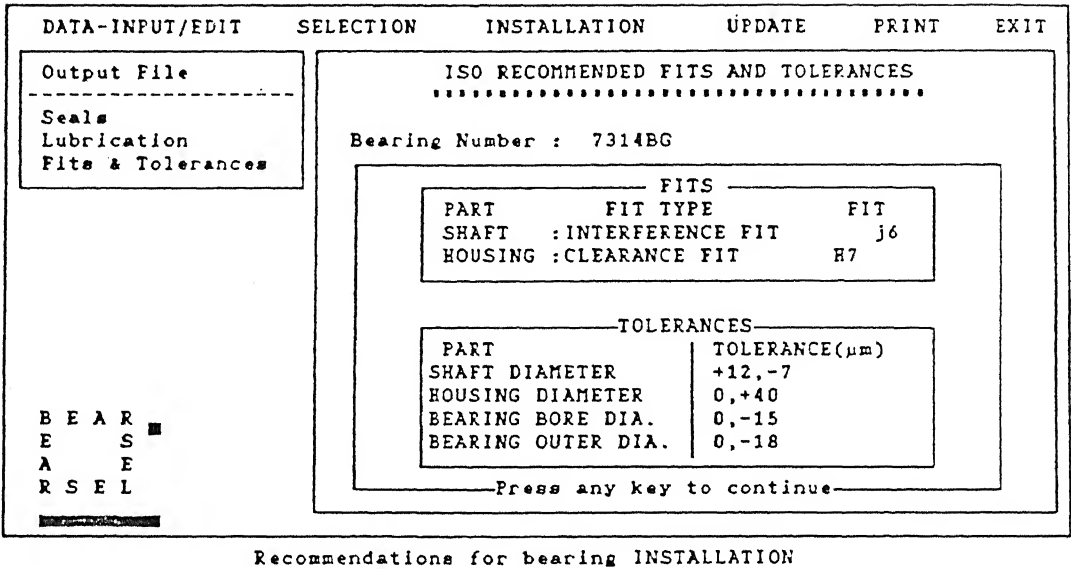


Figure 3.10: Screen printout of fits recommendations

number and company name entered by the user. If bearing record is not found, the relevent bearing attributes are displayed in an appropriate format for the user to enter the values. Otherwise a message saying " Bearing already exists " is flashed on the screen.

In a similar way 'edit' and 'delete' procedure has been designed and implemented. In view option, all bearings available within database are displayed.

The flow chart of implementation procedure for this module is shown in Fig 3.12.

3.6 Printing (PRINT)

The main function of this module is to provide on-line printing facility to the user. This facility has been designed and implemented with four options, such as :

- Input
- Output (Bearings selected)
- Database
- Others

To get the hardcopy of any input, output or bearing database, the user has to select the desired file/database first. The system accordingly retrieves the relevent file/database to be printed and transfers this buffer in the appropriate format to the printer. The flow chart of implementation procedure for this module is shown in Fig.3.13 .

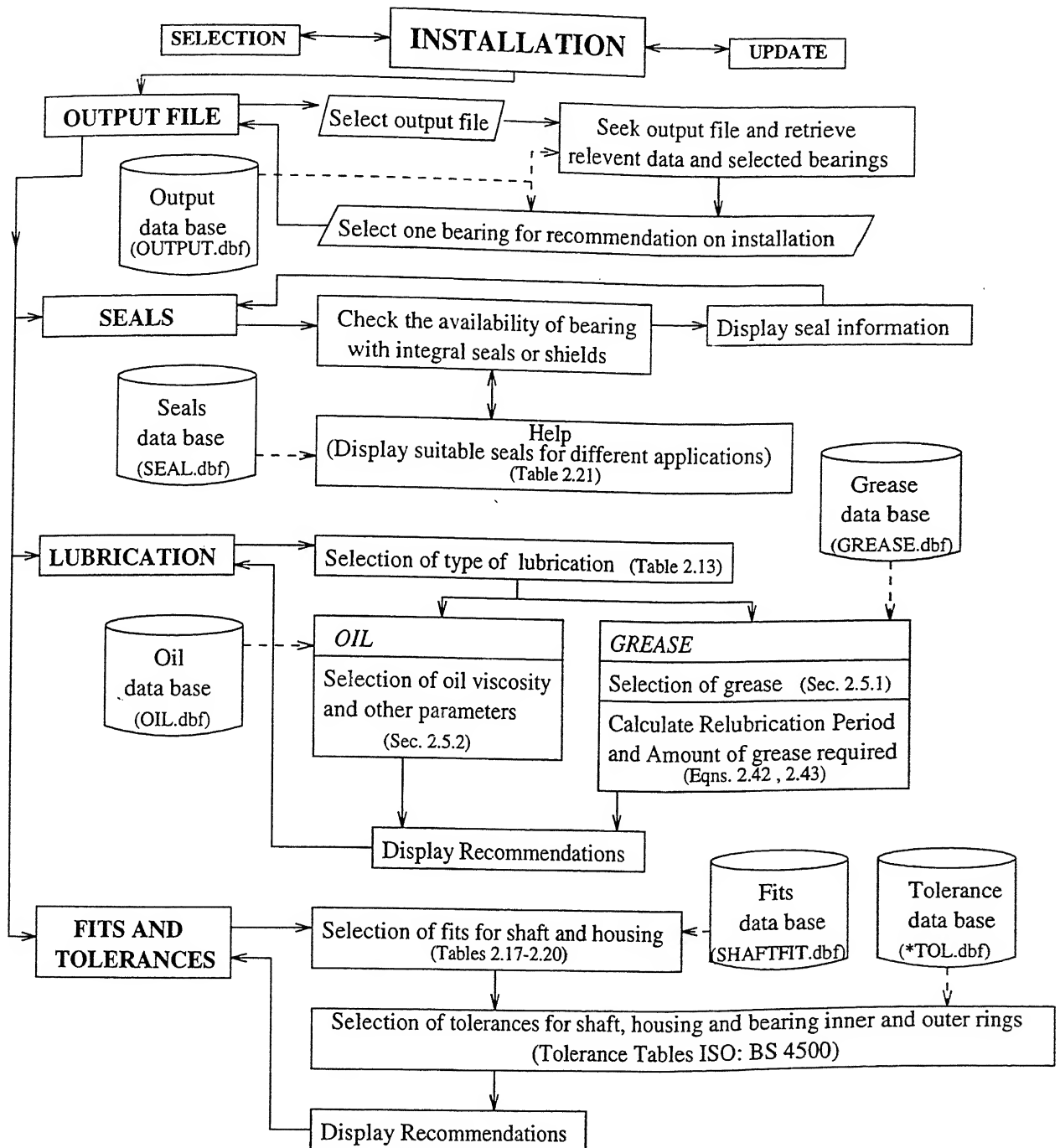


Figure 3.11: Flow chart: Implementation Procedure of INSTALLATION module

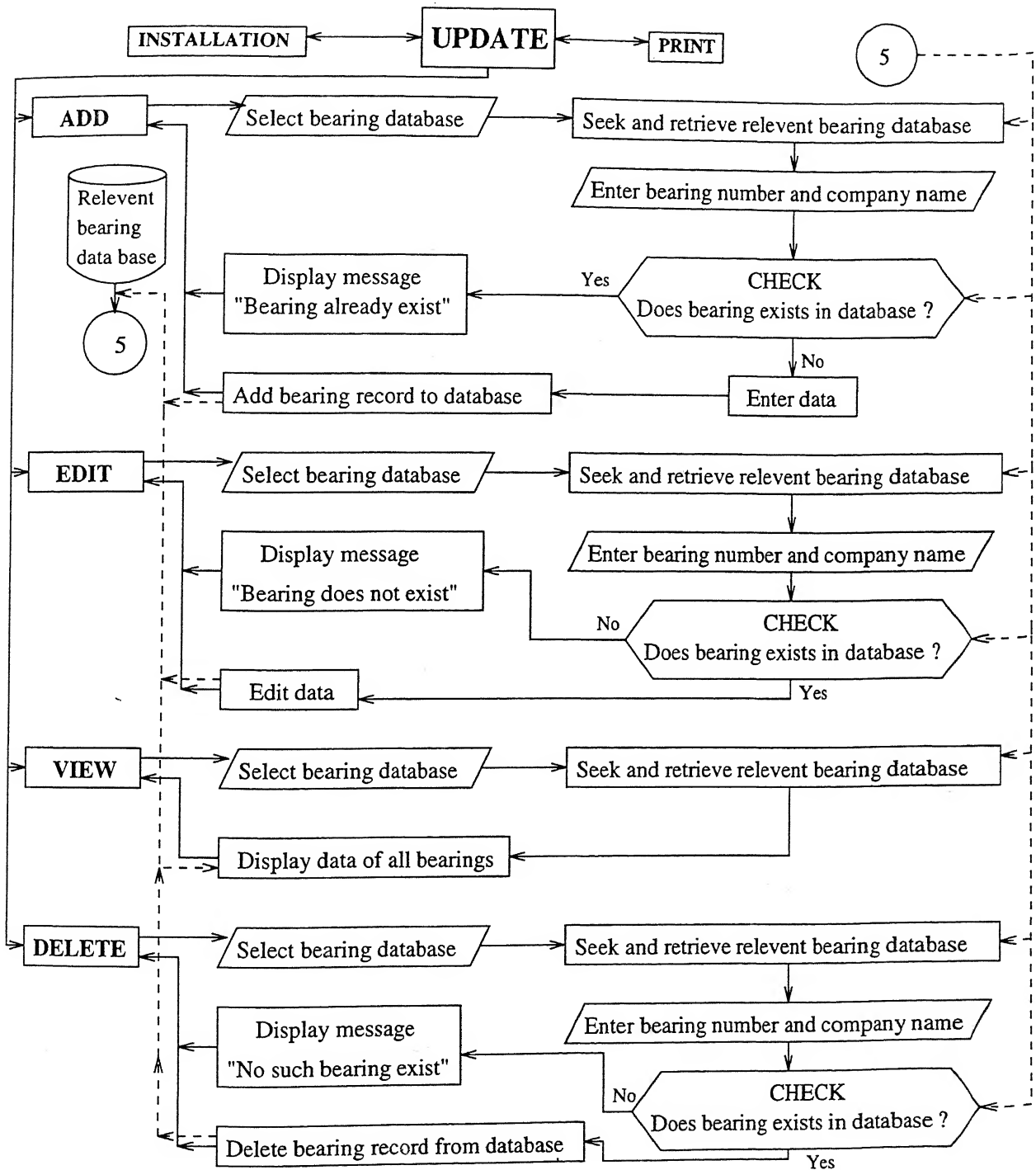


Figure 3.12: Flow chart: Implementation Procedure of UPDATE module

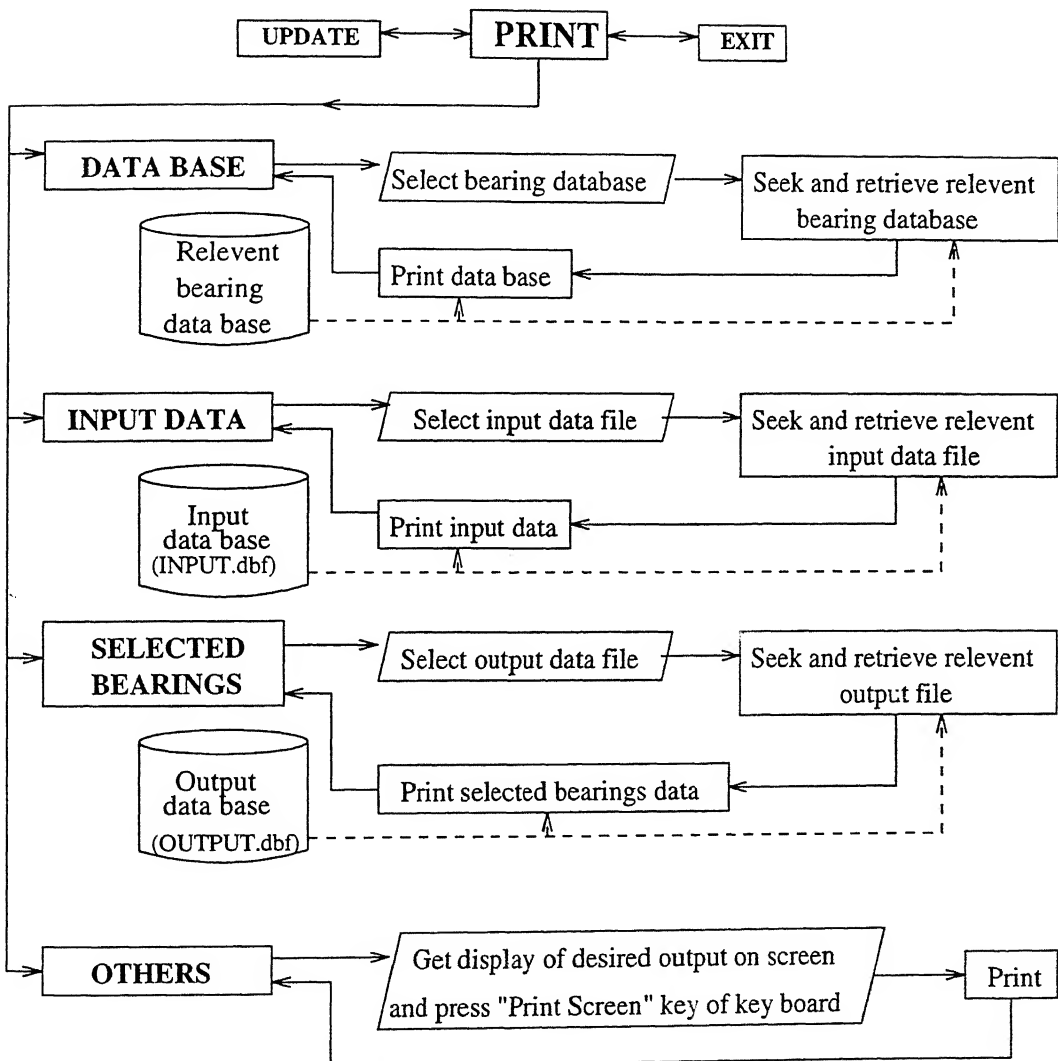


Figure 3.13: Flow chart: Implementation Procedure of PRINT module

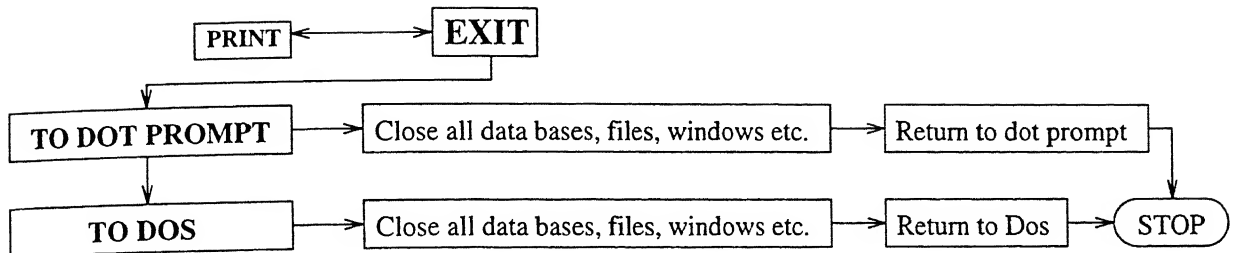


Figure 3.14: Flow chart: Implementation Procedure of EXIT module

3.7 Quitting from the System (EXIT)

After bearing selection is finished and saved, the user may quit the system to either dot prompt or to DOS using this module. Before quitting finally, the system closes all open databases, files and releases all windows, memory variables etc. The implementation procedure is shown in Fig. 3.14 .

3.8 How to use BEARSEL ?

To run the system correctly and efficiently the working with BEARSEL is summarised as follows :

- Step 1** Go to **Data-Input/Edit** option of the main menu and enter the required inputs in the order they are displayed on the screen (top to bottom then left to right for sub and sub-sub-menus). Make sure to enter each and every small piece of input, ignorance may affect the final results (Bearings selected).
- Step 2** Get display of input data to check the correct entry then save it for future use.
- Step 3** Go to the **Selection** option of main menu and select the input file. Now select the bearing types.
- Step 4** Out of the displayed list of suitable bearing types, select one type and then for this bearing type select bearings in three stages in the order based on load ratings, limiting speed and dimensional limits. If in between of any stage no suitable bearings are found, select another bearing type. Finally save these bearings in output file.

Step 5 Go to **Installation** option of the main menu, select finally one bearing and get recommendation for seals, lubrication and fits.

Step 6 Go to **Print** option to get print-out or to **Update** option to update bearing databases.

Step 7 Quit the system with **Exit** option.

3.9 BEARSEL knowledge base and program files

For selection at various steps, the system uses several knowledge base. These are structured in 36 database files whose list with purpose is shown in Table 3.2. The knowledge for these databases has been gathered after extensive study of various manufacturers catalogues [10,12], journals [3,4], books [14,15], hand books [8,9] etc. and expert opinions.

The list of various program files with purpose is described in Table 3.3 . The system summary, tree diagram, structures of all databases and list of different files etc. are shown in Appendix B.

3.10 System Outputs

The outputs of the system are displayed, in appropriate formats, on the screen at various stages of the system run. Hard copies may also be obtained on printer. Sample screen outputs are shown in Appendix A.

Name	Purpose
	Data storage of :
ACBB1.DBF	Angular contact ball bearings (single row)
ACBB2.DBF	Angular contact ball bearings (paired)
ACBB3.DBF	Angular contact ball bearings (double row)
ACTBBS.D.DBF	Angular cont. thru. ball bearings (sing. direction)
ACTBBDD.DBF	Angular cont. thru. ball bearings (doub. direction)
BRB.DBF	Barrel roller bearings
CRB1.DBF	Cylindrical roller bearings (separable rings)
CRB3.DBF	Cylindrical roller bearings (non-separable rings)
CRBDR.DBF	Cylindrical roller bearings (double row)
CRTB.DBF	Cylindrical roller thrust bearings
DGBB1.DBF	Deep groove ball bearings (single row)
DGBB2.DBF	Deep groove ball bearings (double row)
FPCBB.DBF	Four point contact ball bearings
MB.DBF	Magneto bearings
NRB1.DBF	Needle roller bearings
NRB4.DBF	Combined needle roller/ball bearings
NRB5.DBF	Combined needle roller/thrust ball bearings
NRTB.DBF	Needle roller thrust bearings
SABB.DBF	Self aligning ball bearings
SB.DBF	Spindle bearings
SRB1.DBF	Spherical roller bearings
SRTB.DBF	Spherical roller thrust bearings
TBB1.DBF	Thrust ball bearings (single direction)
TBB2.DBF	Thrust ball bearings (double direction)
TRB.DBF	Taper roller bearings
SEAL.DBF	Seal types for different applications
SELECT.DBF	Bearing type suitability and capability
GREASE.DBF	Grease types for different applications
SHAFTFIT.DBF	Fit types for shafts
SHAFTTOL.DBF	Tolerances for shafts
HOUSSETOL.DBF	Tolerances for housings
FLD.DES.DBF	Description for field names of data-bases
SLHELP.DBF	Sudden load type for different applications
OUTPUT.DBF	Finally selected bearings
INPUT.DBF	Input data
LIFEHELP.DBF	requisite life for different applications

Table 3.2: Knowledge-Base of BEARSEL

Name	Purpose
	Calculation of C_{req} and sorting of :
AC_BB1.PRG	Angular contact ball bearings (single row)
AC_BB2.PRG	Angular contact ball bearings (paired)
AC_BB3.PRG	Angular contact ball bearings (double row)
AC_TBBS1.PRG	Angular cont. thru. ball bearings (sing. direction)
AC_TBBS2.PRG	Angular cont. thru. ball bearings (double direction)
BR_B.PRG	Barrel roller bearings
CR_B1.PRG	Cylindrical roller bearings (separable rings)
CR_B3.PRG	Cylindrical roller bearings (non-separable rings)
CR_BDR.PRG	Cylindrical roller bearings (double row)
CR_TB.PRG	Cylindrical roller thrust bearings
DBB1.PRG	Deep groove ball bearings (single row)
DBB2.PRG	Deep groove ball bearings (double row)
FP_CBB.PRG	Four point contact ball bearings
MB.PRG	Magneto bearings
NRB1.PRG	Needle roller bearings
NRB4.PRG	Combined needle roller/ball bearings
NRB5.PRG	Combined needle roller/thrust ball bearings
NR_TB.PRG	Needle roller thrust bearings
SA_BB.PRG	Self aligning ball bearings
SB.PRG	Spindle bearings
SRB1.PRG	Spherical roller bearings
SR_TB.PRG	Spherical roller thrust bearings
TBB1.PRG	Thrust ball bearings (single direction)
TBB2.PRG	Thrust ball bearings (double direction)
TRB.PRG	Taper roller bearings

Table 3.3: Program Files of BEARSEL

Name	Purpose
MAIN.PRG	Master program file
HEAD.PRG	To display first screen of the system
PROCED2.PRG	Procedure file containing common procedures
SPEED.PRG	To get speed input data
LOAD1.PRG	To get load input data
TEMPAR.PRG	To get temperature input data
SUDDEN.PRG	To get sudden load input data and calculate shock factor
RELIABILITY.PRG	To get reliability input data and calculate a_1
LIFE1.PRG	To get life input data
DIMEN1.PRG	To get bearing dimension input data
OPCON1.PRG	To get operating conditions input data
DISPDATA.PRG	To display input data
IDSAVE.PRG	To save input data
ONLYRL1.PRG	To sort bearing types for only radial load
ONLYTL1.PRG	To sort bearing types for only thrust load
COMLOAD1.PRG	To sort bearing types for combined load
SELECT1.PRG	To select input file and input data retrieval
SELECT2.PRG	To select bearing types
SELECT3.PRG	To sort bearings based on speed limits
SELECT4.PRG	To sort bearings based on dimensional limits
ODSAVE.PRG	To save selected bearings
INSTAL.PRG	To select output file and data retrieval
LUBRIC.PRG	To select lubrication
BEARFIT.PRG	To select the fits and tolerances
SEALS.PRG	To select the seals
DBMAN.PRG	To update bearing data-bases
BIP.PRG	To display description of database fields
PRINTDB.PRG	To print bearing data-base
PRINTID.PRG	To print input data
PRINTOT.PRG	To print any displayed screen
PRINTBS.PRG	To print selected bearings

Table 3.3: (continued ...)

Chapter 4

Results and Discussions

The present system, for a given application, first prepares a priority list of suitable bearing types based on certain selection criteria. After the selection of one of the suitable bearing type by the user, the system selects the optimum size bearing(s). The system also recommends the sealing and lubrication methods as well as fits and tolerances to be used while installing the bearing. In this chapter, few examples have been discussed along with their results in the form of screen printouts.

4.1 Example 1 : Bearing selection for a blower

This example considers the bearing selection for a medium size fresh air blower, with overhung arrangement, used in high speed ventilation plants (courtesy: [14], pp 406-409).

4.1.1 Inputs

The design of blower is based on the following data :

Input power	$N = 120 \text{ kW}$
Speed	$n = 3000 \text{ min}^{-1}$
Axial load	$F_a = 6 \text{ kN}$
Weight of impeller	$G_f = 3 \text{ kN}$
Weight of shaft	$G_w = 0.45 \text{ kN}$
Weight of coupling	$G_k = 0.15 \text{ kN}$
Fresh air temperature	$\approx 30^\circ\text{C}$
Ambient temperature	$\approx 35^\circ\text{C}$

The shaft diameter of 70 mm at two bearing locations is determined by the design. Fig. 4.1 shows the bearing load diagram. The imbalance due to gradual dirt accumulation on the impeller is also added to the weight of impeller while calculating radial bearing loads.

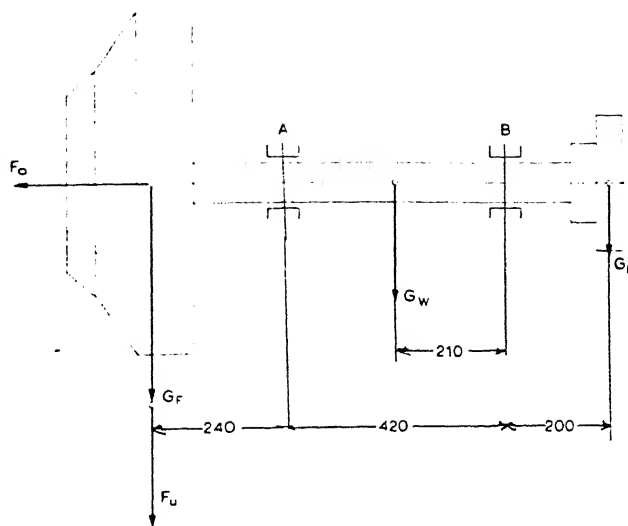


Figure 4.1: Load diagram for the bearings of blower

The loads acting on the two bearing locations are as follows :

bearing A :	$F_r = 7.23 \text{ kN}$	$F_a = 0$
bearing B :	$F_r = 2.12 \text{ kN}$	$F_a = 6 \text{ kN}$

The bearing for the location B is selected where shaft is the rotating part and bearing function is 'locating'. High speed operation makes running accuracy critical and, rigidity and low friction important. The input screen printout is shown in Fig. 4.2.

4.1.2 Outputs

The system suggests the angular contact ball bearing (paired) as most suitable bearing type (shown in Fig. 4.3). The selected optimum sized bearings alongwith recommendations for sealing, lubrication and fits (for the bearing 7314 BG) are shown in Figures 4.4 to 4.7 respectively.

4.1.3 Discussions

The system selects the angular contact ball bearing (ACBB2) as most suitable. While eliminating unsuitable bearing types, system proceeds as follows :

1. Elimination based on bearing speed, like SRTB (having maximum speed available lower than the required (see Table 2.1)).
2. Elimination of bearing types not suitable for combined load, like ACTBBDD, CRB1, NRB1, TBB1 ...etc. (see Table 2.1).

INPUT DATA DISPLAY

SPEED (Constant) RPM VALUE 3000	**RADIAL** (Constant) VALUE 2120	LOAD (Constant) VALUE 6000	**THRUST** DIRECTION Single **SUDDEN** Negligible	RELIABILITY RELIABILITY(%) : 90
				LIFE OPERATING HRS : 40000
				TEMPERATURE MAXIMUM TEMP. : 70 MINIMUM TEMP. : 30
				DIMENSIONS BORE DIA.: MAX. 80 MIN. 70 OUTER DIA: MAX. 0 MIN. 0 WIDTH : MAX. 0 MIN. 0

OPERATING CONDITIONS			
RUNNING ACCURACY : 4	RUNNING QUIETNESS: 1	0 -> UNDESIRABLE:	
SELF ALIGN. CAPABILITY: 1	LOW FRICTION : 3	1 -> USUAL :	
RADIAL RIGIDITY : 3	MAINTENANCE EASE : 1	3 -> DESIRABLE :	
AXIAL RIGIDITY : 3	COST : 1	4 -> CRITICAL :	

PRESS ANY KEY TO CONTINUE

Figure 4.2: Screen printout of Input for Example 1

3. Elimination based on Admissible load ratio ($F_a/F_r = 2.83$), like CRB3, DGBB2, NRB4 ... etc. (see Table 2.1).
4. Elimination based on Bearing Function (locating criteria) like, ACTBBSD, MB ... etc. (see Table 2.1).
5. Elimination based on Running Accuracy as critical like, NRB4, NRB5, SABB ... etc. (see Table 2.3).

In real application angular contact ball bearing (paired), 7314.B.TVP, is being used with k6 and J7 fits for inner and outer bearing rings. Use of Lithium soap grease is quoted [14]. Hence system results appear to be in excellent agreement with actual practice.

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT												
<div style="border: 1px solid black; padding: 5px;"> Input File ----- Bearing Type ----- BEARINGS BASED ON Load Ratings + Speed (rpm) + Dimensional limits ----- Save </div> <div style="margin-top: 20px;"> B E A R ■ E S A E R S E L </div>	<div style="text-align: center; border-bottom: 1px solid black;"> SUITABLE BEARING TYPES ■ </div> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr> <th style="width: 40%;">BEARNAME</th> <th style="width: 20%;">DBNAME</th> <th style="width: 40%;">WEIGHTAGE</th> </tr> </thead> <tbody> <tr> <td>ANGULAR CONT.BALL(2)</td> <td>ACBB2</td> <td style="text-align: right;">58</td> </tr> <tr> <td>ANGULAR CONT.BALL(3)</td> <td>ACBB3</td> <td style="text-align: right;">58</td> </tr> <tr> <td>DEEP GROOVE BALL(1)</td> <td>DGBB1</td> <td style="text-align: right;">57</td> </tr> </tbody> </table> <p style="text-align: center; margin-top: 10px;">(More weightage value indicates higher priority)</p> <p style="text-align: center;">PLEASE SELECT ONE BEARING TYPE</p>					BEARNAME	DBNAME	WEIGHTAGE	ANGULAR CONT.BALL(2)	ACBB2	58	ANGULAR CONT.BALL(3)	ACBB3	58	DEEP GROOVE BALL(1)	DGBB1	57
BEARNAME	DBNAME	WEIGHTAGE															
ANGULAR CONT.BALL(2)	ACBB2	58															
ANGULAR CONT.BALL(3)	ACBB3	58															
DEEP GROOVE BALL(1)	DGBB1	57															

keys and PRESS <Esc>

Figure 4.3: Screen printout of suitable bearing types for Example 1

FINALLY SELECTED SUITABLE BEARINGS									
B_NUMBER	COMPANY	BORE_DIA	OUTER_DIA	WIDTH	C	CO	RPM_OIL	RPM_GRES	M
7314BG	SKF	70	150	70	143000	143000	3800	2800	
7315BG	SKF	75	160	74	153000	160000	3600	2600	
7316BG	SKF	80	170	78	166000	180000	3400	2400	

B_NUMBER : Bearing Number
 C : Dynamic Load Rating(Newtons)
 CO : Static Load Rating(Newtons)
 RPM_* : Limiting Speeds(rpm)
 MASS : Weight of bearing(g)
 Linear Dimensions are in m.m.

PRESS [ESC] TO CONTINUE FURTHER

Use keys to see all BEARINGS and SPECIFICATIONS

Figure 4.4: Screen printout of finally selected bearings for Example 1

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT										
<div style="border: 1px solid black; padding: 5px;"> Output File ----- Seals Lubrication Fits & Tolerances </div>	SEALS & SHIELDS Bearing Number : 7314BG														
<div style="border: 1px solid black; padding: 10px; margin: 10px auto; width: 80%;"> BEARING AVAILABILITY <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">WITH (Integral)</th> <th style="text-align: left;">STATUS</th> </tr> </thead> <tbody> <tr> <td>SINGLE SEAL</td> <td>No</td> </tr> <tr> <td>DOUBLE SEALS</td> <td>No</td> </tr> <tr> <td>SINGLE SHIELD</td> <td>No</td> </tr> <tr> <td>DOUBLE SHIELDS</td> <td>No</td> </tr> </tbody> </table> </div>						WITH (Integral)	STATUS	SINGLE SEAL	No	DOUBLE SEALS	No	SINGLE SHIELD	No	DOUBLE SHIELDS	No
WITH (Integral)	STATUS														
SINGLE SEAL	No														
DOUBLE SEALS	No														
SINGLE SHIELD	No														
DOUBLE SHIELDS	No														
<div style="border: 1px solid black; padding: 5px; margin: 10px auto; width: 80%;"> NOTE : To select SEALS for UNSEALED BEARINGS PRESS key F2 </div>															
_____ press any key to continue _____															

Recommendations for bearing INSTALLATION

Figure 4.5: Screen printout of recommendations for seals for Example 1

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT										
<div style="border: 1px solid black; padding: 5px;"> Output File ----- Seals Lubrication Fits & Tolerances </div>	LUBRICATION DETAILS Bearing Number : 7314BG														
<div style="border: 1px solid black; padding: 10px; margin: 10px auto; width: 80%;"> SPECIFICATIONS <table style="width: 100%; border-collapse: collapse;"> <tbody> <tr> <td>LUBRICANT</td> <td>: GREASE</td> </tr> <tr> <td>GREASE CODE</td> <td>: L-XG-271</td> </tr> <tr> <td>QUANTITY REQD. (g)</td> <td>: 52.50</td> </tr> <tr> <td>REGREASE PERIOD(Hrs)</td> <td>: 13933.20</td> </tr> <tr> <td>NLGI No</td> <td>: 2 OR 3</td> </tr> </tbody> </table> </div>						LUBRICANT	: GREASE	GREASE CODE	: L-XG-271	QUANTITY REQD. (g)	: 52.50	REGREASE PERIOD(Hrs)	: 13933.20	NLGI No	: 2 OR 3
LUBRICANT	: GREASE														
GREASE CODE	: L-XG-271														
QUANTITY REQD. (g)	: 52.50														
REGREASE PERIOD(Hrs)	: 13933.20														
NLGI No	: 2 OR 3														
<div style="border: 1px solid black; padding: 5px; margin: 10px auto; width: 80%;"> ADVICE : Fill grease upto 30-50 % of free space Over packing may cause over heating </div>															
<div style="border: 1px solid black; padding: 5px; margin: 10px auto; width: 80%;"> NOTE : For GREASE CODE description press F2 Press any key to continue </div>															

Recommendations for bearing INSTALLATION

Figure 4.6: Screen printout of recommendations for lubrication for Example 1

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT																			
<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> Output File ----- Seals Lubrication Fits & Tolerances </div> <div style="display: flex; justify-content: space-between;"> B E A R ■ </div> <div style="display: flex; justify-content: space-between;"> E S </div> <div style="display: flex; justify-content: space-between;"> A E </div> <div style="display: flex; justify-content: space-between;"> R S E L </div>		<div style="text-align: center; border-bottom: 1px solid black; margin-bottom: 10px;"> ISO RECOMMENDED FITS AND TOLERANCES </div> <p>Bearing Number : 7314BG</p> <div style="border: 1px solid black; padding: 10px; margin: 10px 0;"> <div style="text-align: center; border-bottom: 1px solid black; margin-bottom: 5px;">FITS</div> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">PART</th> <th style="text-align: left;">FIT TYPE</th> <th style="text-align: left;">FIT</th> </tr> </thead> <tbody> <tr> <td>SHAFT</td> <td>: INTERFERENCE FIT</td> <td>j6</td> </tr> <tr> <td>HOUSING</td> <td>: CLEARANCE FIT</td> <td>H7</td> </tr> </tbody> </table> </div> <div style="border: 1px solid black; padding: 10px; margin: 10px 0;"> <div style="text-align: center; border-bottom: 1px solid black; margin-bottom: 5px;">TOLERANCES</div> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">PART</th> <th style="text-align: left;">TOLERANCE (μm)</th> </tr> </thead> <tbody> <tr> <td>SHAFT DIAMETER</td> <td>+12, -7</td> </tr> <tr> <td>HOUSING DIAMETER</td> <td>0, +40</td> </tr> <tr> <td>BEARING BORE DIA.</td> <td>0, -15</td> </tr> <tr> <td>BEARING OUTER DIA.</td> <td>0, -18</td> </tr> </tbody> </table> </div> <p style="text-align: center; margin-top: 10px;">Press any key to continue</p>				PART	FIT TYPE	FIT	SHAFT	: INTERFERENCE FIT	j6	HOUSING	: CLEARANCE FIT	H7	PART	TOLERANCE (μm)	SHAFT DIAMETER	+12, -7	HOUSING DIAMETER	0, +40	BEARING BORE DIA.	0, -15	BEARING OUTER DIA.	0, -18
PART	FIT TYPE	FIT																						
SHAFT	: INTERFERENCE FIT	j6																						
HOUSING	: CLEARANCE FIT	H7																						
PART	TOLERANCE (μm)																							
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HOUSING DIAMETER	0, +40																							
BEARING BORE DIA.	0, -15																							
BEARING OUTER DIA.	0, -18																							

Recommendations for bearing INSTALLATION

Figure 4.7: Screen printout of recommendations for fits for Example 1

4.2 Example 2 : Bearing selection for the traction motor of an electric locomotive

Traction motors do not operate continuously or with a constant output. The operation is intermittent and the loads on the traction motor bearings vary considerably in magnitude and direction (courtesy: [14], pp 416-419).

4.2.1 Inputs

The following data are available for the bearing calculation :

Hourly output power	$N_h = 1250 \text{ kW}$
Hourly speed	$n_h = 1300 \text{ min}^{-1}$
Maximum rotational speed	$n_{max} = 1500 \text{ min}^{-1}$
Maximum travel speed	$v_{max} = 200 \text{ km/h}$
Armature weight	$G_L = 13.5 \text{ kN}$
Pinion pitch circle diameter	$d_o = 521.3 \text{ mm}$
Pressure angle	$\alpha_E = 20^\circ$
Spiral angle	$\beta = 4^\circ$

Fig. 4.8 shows the bearing load diagram.

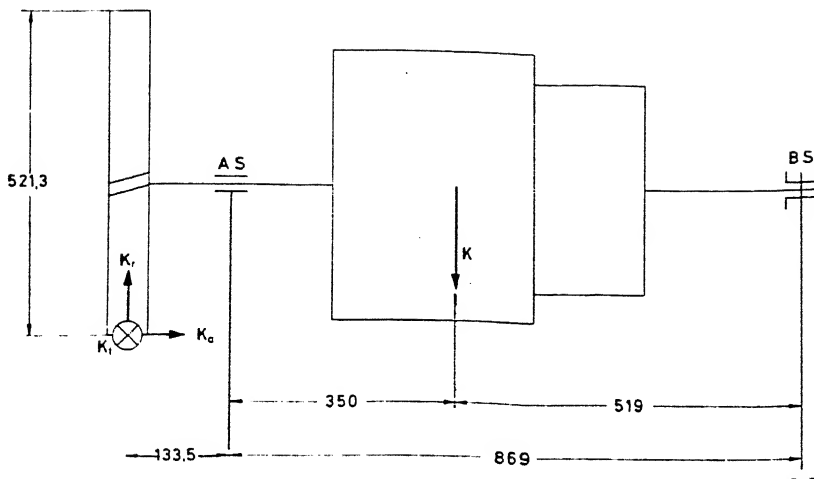


Figure 4.8: Load diagram for the bearings of traction motor

The determined tooth load acting on the pinion based on hourly output calculation are as follows :

Tangential load	$K_t = 22.9 \text{ kN}$
Radial load	$K_r = 8.36 \text{ kN}$
Axial load	$K_a = 1.6 \text{ kN}$

The bearings are additionally loaded by the rotor weight, imbalance loads and shock loads occurring in operation. The changing direction of travel of the locomotive is considered and, as a rule, 50 % of the mileage is assumed for either direction of travel. The shaft diameters of 130 and 90 mm at two bearing locations AS and BS are determined by the design. The bearing loads for both direction of rotation acting on the two bearing locations AS and BS are as follows :

Bearing location	Bearing loads [kN]	
	<i>anticlockwise rotation</i>	<i>clockwise rotation</i>
AS	$F_r = 13.67$	$F_r = 13.55$
BS	$F_r = 6.1; F_a = 0.8$	$F_r = 6.575; F_a = 0.8$

The bearing for the location BS is selected where operating conditions makes running accuracy and low friction, critical and radial rigidity important. The input screen printout is shown in Fig. 4.9.

4.2.2 Outputs

For bearing at location BS the system suggests the angular contact ball bearing and cylindrical roller bearing as most suitable bearing type (shown in Fig.4.10). The selected

INPUT DATA DISPLAY			
SPEED (Constant)	**RADIAL** (Step Load)	LOAD (Constant)	**THRUST**
RPM VALUE 1300	STEPS: 2 VALUE 1 6100 50 6575 50	VALUE 800	DIRECTION Double
			SUDDEN
			Medium Shock
			RELIABILITY RELIABILITY(%) : 90
			LIFE RUNNING KMS(million): 3.00 WHEEL DIA. : 0.52
			TEMPERATURE MAXIMUM TEMP. : 90 MINIMUM TEMP. : 30
			DIMENSIONS BORE DIA.: MAX. 95 MIN. 90 OUTER DIA: MAX. 0 MIN. 0 WIDTH : MAX. 0 MIN. 0
OPERATING CONDITIONS			
RUNNING ACCURACY : 4	RUNNING QUIETNESS: 1	0 -> UNDESIRABLE:	
SELF ALIGN. CAPABILITY: 1	LOW FRICTION : 4	1 -> USUAL :	
RADIAL RIGIDITY : 3	MAINTENANCE EASE : 1	3 -> DESIRABLE :	
AXIAL RIGIDITY : 1	COST : 1	4 -> CRITICAL :	

PRESS ANY KEY TO CONTINUE

Figure 4.9: Screen printout of Input for Example 2

optimum sized bearings alongwith recommendations for sealing, lubrication and fits (for the cylindrical roller bearing NJ 318) are shown in Figures 4.11 to 4.14 respectively.

4.2.3 Discussions

The system provides more options to the user by selecting bearings of more than one type. In real application cylindrical roller bearing NJ318.M, is used lubricated with Lithium soap grease. Due to shock type and frequently very high loads relatively tight fits are chosen (n5 and k6 for inner and outer bearing rings).

Comparison of system results with actual application data validates the system functionality.

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT												
<div style="border: 1px solid black; padding: 2px;"> Input File ----- Bearing Type ----- BEARINGS BASED ON Load Ratings + Speed (rpm) + Dimensional limits ----- Save </div> <div style="margin-top: 20px;"> B E A R E S A E R S E L </div>	<div style="border: 1px solid black; padding: 5px;"> <h3 style="text-align: center; margin: 0;">SUITABLE BEARING TYPES</h3> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr> <th style="text-align: left;">BEARNAME</th> <th style="text-align: left;">DBNAME</th> <th style="text-align: left;">WEIGHTAGE</th> </tr> </thead> <tbody> <tr> <td>ANGULAR CONT.BALL(2)</td> <td>ACBB2</td> <td>59</td> </tr> <tr> <td>DEEP GROOVE BALL(1)</td> <td>DGGB1</td> <td>59</td> </tr> <tr> <td>CLYNDRICAL ROLLER(3)</td> <td>CRB3</td> <td>56</td> </tr> </tbody> </table> <p style="text-align: center; margin-top: 10px;">(More weightage value indicates higher priority)</p> <p style="text-align: center; margin-top: 10px;">PLEASE SELECT ONE BEARING TYPE</p> </div>					BEARNAME	DBNAME	WEIGHTAGE	ANGULAR CONT.BALL(2)	ACBB2	59	DEEP GROOVE BALL(1)	DGGB1	59	CLYNDRICAL ROLLER(3)	CRB3	56
BEARNAME	DBNAME	WEIGHTAGE															
ANGULAR CONT.BALL(2)	ACBB2	59															
DEEP GROOVE BALL(1)	DGGB1	59															
CLYNDRICAL ROLLER(3)	CRB3	56															

keys and PRESS <Esc>

Figure 4.10: Screen printout of suitable bearing types for Example 2

FINALLY SELECTED SUITABLE BEARINGS								
B_NUMBER	COMPANY	BORE_DIA	OUTER_DIA	WIDTH	C	CO	RPM_OIL	RPM_GRES
NJ318	SKF	90	190	43	220000	160000	3800	3200
NJ2318	SKF	90	190	64	300000	240000	3400	2800
NUP218	SKF	90	160	30	134000	100000	4500	3800
NJ418	SKF	90	225	54	345000	260000	3400	2800
NJ2218	SKF	90	160	40	186000	150000	4300	3600
NUP2218	SKF	90	160	40	186000	150000	4300	3600
NJ218	SKF	90	160	30	134000	100000	4500	3800
NUP2318	SKF	90	190	64	300000	240000	3400	2800
NUP318	SKF	90	190	43	220000	160000	3800	3200

B_NUMBER : Bearing Number
 C : Dynamic Load Rating(Newtons)
 CO : Static Load Rating(Newtons)
 RPM * : Limiting Speeds(rpm)
 MASS : Weight of bearing(g)
 Linear Dimensions are in m.m.

PRESS [ESC] TO CONTINUE FURTHER

Use keys to see all BEARINGS and SPECIFICATIONS

Figure 4.11: Screen printout of finally selected bearings for Example 2

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT										
<div style="border: 1px solid black; padding: 5px;"> Output File ----- Seals Lubrication Fits & Tolerances </div>	SEALS & SHIELDS														
Bearing Number : NJ318															
<div style="border: 1px solid black; padding: 5px;"> BEARING AVAILABILITY </div>															
<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 60%;">WITH (Integral)</th> <th style="width: 40%;">STATUS</th> </tr> </thead> <tbody> <tr> <td>SINGLE SEAL</td> <td>No</td> </tr> <tr> <td>DOUBLE SEALS</td> <td>No</td> </tr> <tr> <td>SINGLE SHIELD</td> <td>No</td> </tr> <tr> <td>DOUBLE SHIELDS</td> <td>No</td> </tr> </tbody> </table>						WITH (Integral)	STATUS	SINGLE SEAL	No	DOUBLE SEALS	No	SINGLE SHIELD	No	DOUBLE SHIELDS	No
WITH (Integral)	STATUS														
SINGLE SEAL	No														
DOUBLE SEALS	No														
SINGLE SHIELD	No														
DOUBLE SHIELDS	No														
<div style="border: 1px solid black; padding: 5px; text-align: center;"> NOTE : To select SEALS for UNSEALED BEARINGS PRESS key F2 </div>															
press any key to continue															

Recommendations for bearing INSTALLATION

Figure 4.12: Screen printout of recommendations for seals for Example 2

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT												
<div style="border: 1px solid black; padding: 5px;"> Output File ----- Seals Lubrication Fits & Tolerances </div>	LUBRICATION DETAILS																
Bearing Number : NJ318																	
<div style="border: 1px solid black; padding: 5px;"> SPECIFICATIONS </div>																	
<table style="width: 100%; border-collapse: collapse;"> <tbody> <tr> <td style="width: 60%;">LUBRICANT</td> <td style="width: 40%;">GREASE</td> </tr> <tr> <td>GREASE CODE</td> <td>L-XG-271</td> </tr> <tr> <td>QUANTITY REQD. (g)</td> <td>40.85</td> </tr> <tr> <td>REGREASE PERIOD(Hrs)</td> <td>3875.88</td> </tr> <tr> <td>NLGI No</td> <td>2 OR 3</td> </tr> <tr> <td colspan="2">USE EXTREME PRESSURE(EP) GREASE</td> </tr> </tbody> </table>						LUBRICANT	GREASE	GREASE CODE	L-XG-271	QUANTITY REQD. (g)	40.85	REGREASE PERIOD(Hrs)	3875.88	NLGI No	2 OR 3	USE EXTREME PRESSURE(EP) GREASE	
LUBRICANT	GREASE																
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<div style="border: 1px solid black; padding: 5px;"> ADVICE : Fill grease upto 30-50 % of free space Over packing may cause over heating </div>																	
<div style="border: 1px solid black; padding: 5px; text-align: center;"> NOTE : For GREASE CODE description press F2 Press any key to continue </div>																	

Recommendations for bearing INSTALLATION

Figure 4.13: Screen printout of recommendations for lubrication for Example 2

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT																			
<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> Output File ----- Seals Lubrication Fits & Tolerances </div> <div style="display: flex; justify-content: space-between;"> <div style="width: 40%;"> B E A R E S A E R S E L </div> <div style="width: 10%; text-align: center;"> <input checked="" type="checkbox"/> </div> </div>	ISO RECOMMENDED FITS AND TOLERANCES Bearing Number : NJ318 <div style="border: 1px solid black; padding: 10px; margin: 10px auto; width: 80%;"> <div style="text-align: center; border-bottom: 1px solid black; margin-bottom: 10px;"> FITS </div> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">PART</th> <th style="text-align: left;">FIT TYPE</th> <th style="text-align: left;">FIT</th> </tr> </thead> <tbody> <tr> <td>SHAFT</td> <td>: INTERFERENCE FIT</td> <td>k6</td> </tr> <tr> <td>HOUSING</td> <td>: INTERFERENCE FIT</td> <td>K7</td> </tr> </tbody> </table> <div style="text-align: center; border-bottom: 1px solid black; margin-bottom: 10px;"> TOLERANCES </div> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">PART</th> <th style="text-align: left;">TOLERANCE (μm)</th> </tr> </thead> <tbody> <tr> <td>SHAFT DIAMETER</td> <td>+25, +3</td> </tr> <tr> <td>HOUSING DIAMETER</td> <td>+13, -33</td> </tr> <tr> <td>BEARING BORE DIA.</td> <td>0, -20</td> </tr> <tr> <td>BEARING OUTER DIA.</td> <td>0, -30</td> </tr> </tbody> </table> <p style="text-align: center; margin-top: 10px;">—Press any key to continue—</p> </div>					PART	FIT TYPE	FIT	SHAFT	: INTERFERENCE FIT	k6	HOUSING	: INTERFERENCE FIT	K7	PART	TOLERANCE (μm)	SHAFT DIAMETER	+25, +3	HOUSING DIAMETER	+13, -33	BEARING BORE DIA.	0, -20	BEARING OUTER DIA.	0, -30
PART	FIT TYPE	FIT																						
SHAFT	: INTERFERENCE FIT	k6																						
HOUSING	: INTERFERENCE FIT	K7																						
PART	TOLERANCE (μm)																							
SHAFT DIAMETER	+25, +3																							
HOUSING DIAMETER	+13, -33																							
BEARING BORE DIA.	0, -20																							
BEARING OUTER DIA.	0, -30																							
Recommendations for bearing INSTALLATION																								

Figure 4.14: Screen printout of recommendations for fits for Example 2

4.3 Example 3 : Bearing selection for a ship propeller thrust block

The thrust block is the locating bearing of the line shaft and transmits the propeller end thrust from the shaft to the ship. Apart from a small radial load from the shaft weight, the bearing is loaded by a purely axial load which acts forward or backward, depending on the direction of the propeller rotation. The thrust must feature self aligning capability to compensate for misalignment resulting from distortion of the ship's hull, shaft deflection and small mismatch of shaft and housing. The design of thrust block is based on the propeller thrust (depends on the engine output), speed and shaft diameter (courtesy: [14], pp 451-456).

4.3.1 Inputs

The following data are available for the bearing calculation :

	Normal load	Full load
Engine output	$N_1 = 258 \text{ kW}$	$N_2 = 316 \text{ kW}$
	$n_1 = 375 \text{ min}^{-1}$	$n_2 = 500 \text{ min}^{-1}$
Proportionate running times	$q_1 = 75\%$	$q_2 = 25\%$
Resulting axial loads	$F_{a1} = 49 \text{ kN}$	$F_{a2} = 60 \text{ kN}$

The minimum shaft diameter of 130 mm is to be used. The input screen printout is shown in Fig. 4.15.

INPUT DATA DISPLAY

SPEED (Variable) STEPS: 2 VALUES % 375 75 500 25	LOAD <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> **RADIAL** (Negligible) </div> <div style="width: 45%;"> **THRUST** (Step Load) </div> </div> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> VALUE % 49000 75 60000 25 </div> <div style="width: 45%;"> DIRECTION Double **SUDDEN** Negligible </div> </div>	RELIABILITY RELIABILITY(%) : 90 LIFE OPERATING HRS : 30000 TEMPERATURE MAXIMUM TEMP. : 80 MINIMUM TEMP. : 30 DIMENSIONS BORE DIA.: MAX. 150 MIN. 130 OUTER DIA: MAX. 0 MIN. 0 WIDTH : MAX. 0 MIN. 0
--	--	---

OPERATING CONDITIONS			
RUNNING ACCURACY	: 3	RUNNING QUIETNESS: 1	0 -> UNDESIRABLE:
SELF ALIGN. CAPABILITY:	: 4	LOW FRICTION	: 1 1 -> USUAL :
RADIAL RIGIDITY	: 1	MAINTENANCE EASE	: 1 3 -> DESIRABLE :
AXIAL RIGIDITY	: 3	COST	: 1 4 -> CRITICAL :

PRESS ANY KEY TO CONTINUE

Figure 4.15: Screen printout of Input for Example 3

4.3.2 Outputs

The system suggests the Spherical roller bearing 22330 C, as most suitable bearing. The various system outputs are shown in Figures 4.16 to 4.20 respectively.

4.3.3 Discussions

System eliminate all the bearing types other than BRB, SABB, SRB1, and SRTB because self aligning capability is critical (see Table 2.3). Further, by ranking suitable bearing types, it gives top priority to spherical roller bearing because of its thrust and shock load capacities (see Table 2.1). In real application the author [14] suggests the use of spherical roller bearing 22328 ES, with k6 or m6 fit for shaft and H7 (loose fit) for housing. Comparison again validates the system results.

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT									
<div style="border: 1px solid black; padding: 2px;"> Input File ----- Bearing Type ----- BEARINGS BASED ON Load Ratings + Speed (rpm) + Dimensional limits ----- Save </div> <div style="margin-top: 20px;"> B E A R ■ E S ■ A E R S E L </div>	<div style="border: 1px solid black; padding: 5px;"> <h3 style="text-align: center; margin: 0;">SUITABLE BEARING TYPES ■</h3> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr> <th style="text-align: left;">BEARNAME</th> <th style="text-align: left;">DBNAME</th> <th style="text-align: left;">WEIGHTAGE</th> </tr> </thead> <tbody> <tr> <td>DEEP GROOVE BALL(1)</td> <td>DGBB1</td> <td style="text-align: right;">44</td> </tr> <tr> <td>SPHERICAL ROLLER</td> <td>SRB1</td> <td style="text-align: right;">43</td> </tr> </tbody> </table> <p style="text-align: center; margin-top: 10px;">(More weightage value indicates higher priority)</p> <p style="text-align: center;">PLEASE SELECT ONE BEARING TYPE</p> </div>					BEARNAME	DBNAME	WEIGHTAGE	DEEP GROOVE BALL(1)	DGBB1	44	SPHERICAL ROLLER	SRB1	43
BEARNAME	DBNAME	WEIGHTAGE												
DEEP GROOVE BALL(1)	DGBB1	44												
SPHERICAL ROLLER	SRB1	43												

keys and PRESS <Esc>

Figure 4.16: Screen printout of suitable bearing types for Example 3

FINALLY SELECTED SUITABLE BEARINGS								
B_NUMBER	COMPANY	BORE_DIA	OUTER_DIA	WIDTH	C	CO	RPM_OIL	RPM_GR
22330C	SKF	150	320	108	1120000	1040000	1400	1000

B_NUMBER : Bearing Number
 C : Dynamic Load Rating(Newtons)
 CO : Static Load Rating(Newtons)
 RPM_* : Limiting Speeds(rpm)
 MASS : Weight of bearing(g)
 Linear Dimensions are in m.m.

PRESS [ESC] TO CONTINUE FURTHER
 Use keys to see all BEARINGS and SPECIFICATIONS

Figure 4.17: Screen printout of finally selected bearings for Example 3

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT										
<div style="border: 1px solid black; padding: 5px;"> Output File <hr style="border-top: 1px dashed black;"/> Seals Lubrication Fits & Tolerances </div>	SEALS & SHIELDS														
Bearing Number : 22330C															
<div style="border: 1px solid black; padding: 10px; margin: 10px auto; width: 80%;"> <p style="text-align: center;">BEARING AVAILABILITY</p> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">WITH (Integral)</th> <th style="text-align: left;">STATUS</th> </tr> </thead> <tbody> <tr> <td>SINGLE SEAL</td> <td>No</td> </tr> <tr> <td>DOUBLE SEALS</td> <td>No</td> </tr> <tr> <td>SINGLE SHIELD</td> <td>No</td> </tr> <tr> <td>DOUBLE SHIELDS</td> <td>No</td> </tr> </tbody> </table> </div>						WITH (Integral)	STATUS	SINGLE SEAL	No	DOUBLE SEALS	No	SINGLE SHIELD	No	DOUBLE SHIELDS	No
WITH (Integral)	STATUS														
SINGLE SEAL	No														
DOUBLE SEALS	No														
SINGLE SHIELD	No														
DOUBLE SHIELDS	No														
<div style="border: 1px solid black; padding: 5px; margin: 10px auto; width: 80%;"> NOTE : To select SEALS for UNSEALED BEARINGS PRESS key F2 </div>															
press any key to continue															

Recommendations for bearing INSTALLATION

Figure 4.18: Screen printout of recommendations for seals for Example 3

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT						
<div style="border: 1px solid black; padding: 5px;"> Output File <hr style="border-top: 1px dashed black;"/> Seals Lubrication Fits & Tolerances </div>	LUBRICATION DETAILS										
Bearing Number : 22330C											
<div style="border: 1px solid black; padding: 10px; margin: 10px auto; width: 80%;"> <p style="text-align: center;">SPECIFICATIONS</p> <table style="width: 100%; border-collapse: collapse;"> <tbody> <tr> <td style="width: 40%;">LUBRICANT</td> <td>: Oil</td> </tr> <tr> <td>VISCOSITY(cst)</td> <td>: 67.33</td> </tr> <tr> <td>VISCOSITY INDEX</td> <td>: Medium OR High</td> </tr> </tbody> </table> </div>						LUBRICANT	: Oil	VISCOSITY(cst)	: 67.33	VISCOSITY INDEX	: Medium OR High
LUBRICANT	: Oil										
VISCOSITY(cst)	: 67.33										
VISCOSITY INDEX	: Medium OR High										
<div style="border: 1px solid black; padding: 5px; margin: 10px auto; width: 80%;"> ADVICE : For centralised oil lubrication system same oil may also be used for the bearing </div>											
Press any key to continue											

Recommendations for bearing INSTALLATION

Figure 4.19: Screen printout of recommendations for lubrication for Example 3

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT																								
<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> Output File ----- Seals Lubrication Fits & Tolerances </div> <div style="display: flex; justify-content: space-between;"> B E A R ■ </div> <div style="display: flex; justify-content: space-between;"> E S </div> <div style="display: flex; justify-content: space-between;"> A E </div> <div style="display: flex; justify-content: space-between;"> R S E L </div>	ISO RECOMMENDED FITS AND TOLERANCES Bearing Number : 22330C <div style="border: 1px solid black; padding: 10px; margin: 10px auto; width: 80%;"> <table style="width: 100%; border-collapse: collapse;"> <tr> <th colspan="3" style="text-align: center; border-bottom: 1px solid black;">FITS</th> </tr> <tr> <th style="width: 30%;">PART</th> <th style="width: 40%;">FIT TYPE</th> <th style="width: 30%;">FIT</th> </tr> <tr> <td>SHAFT</td> <td>: TRANSITION FIT</td> <td>j6</td> </tr> <tr> <td>HOUSING</td> <td>: TRANSITION FIT</td> <td>H8</td> </tr> </table> <table style="width: 100%; border-collapse: collapse;"> <tr> <th colspan="2" style="text-align: center; border-bottom: 1px solid black;">TOLERANCES</th> </tr> <tr> <th style="width: 60%;">PART</th> <th style="width: 40%;">TOLERANCE(μm)</th> </tr> <tr> <td>SHAFT DIAMETER</td> <td>+14, -11</td> </tr> <tr> <td>HOUSING DIAMETER</td> <td>0, +89</td> </tr> <tr> <td>BEARING BORE DIA.</td> <td>0, -25</td> </tr> <tr> <td>BEARING OUTER DIA.</td> <td>0, -40</td> </tr> </table> </div> <p style="text-align: center; margin-top: 10px;">— Press any key to continue —</p>					FITS			PART	FIT TYPE	FIT	SHAFT	: TRANSITION FIT	j6	HOUSING	: TRANSITION FIT	H8	TOLERANCES		PART	TOLERANCE(μm)	SHAFT DIAMETER	+14, -11	HOUSING DIAMETER	0, +89	BEARING BORE DIA.	0, -25	BEARING OUTER DIA.	0, -40
FITS																													
PART	FIT TYPE	FIT																											
SHAFT	: TRANSITION FIT	j6																											
HOUSING	: TRANSITION FIT	H8																											
TOLERANCES																													
PART	TOLERANCE(μm)																												
SHAFT DIAMETER	+14, -11																												
HOUSING DIAMETER	0, +89																												
BEARING BORE DIA.	0, -25																												
BEARING OUTER DIA.	0, -40																												

Recommendations for bearing INSTALLATION

Figure 4.20: Screen printout of recommendations for fits for Example 3

4.4 Example 4 : Bearing selection for a conveyor belt idler

4.4.1 Inputs

The following data are available for the bearing calculation (courtesy: [14], pp 409-413) :

Capacity	3100 tonnes/h
Belt speed	3.5 m/s
Belt width	1000 mm
Trough angle	30°
Idler diameter	108 mm
Axle diameter	20 mm
Idler length	380 mm
distance between two idler stations	1.5 m
Belt weight	25 kg/m
Weight of rotating parts of one idler	12 kg

Each idler is supported with two bearings with radial load $F_r = 1.38 \text{ kN}$ on each bearing at the idler speed of 620 min^{-1} . Application dictates the self aligning capability as critical. The input screen printout is shown in Fig. 4.21.

INPUT DATA DISPLAY				
SPEED (Constant)		LOAD		RELIABILITY
RPM VALUE 620		**RADIAL** (Constant) VALUE 1380	**THRUST** (Negligible) DIRECTION Single	RELIABILITY(%) : 90
				LIFE
				OPERATING HRS : 30000
				TEMPERATURE
				MAXIMUM TEMP. : 50
				MINIMUM TEMP. : 30
				DIMENSIONS
				BORE DIA.: MAX. 25 MIN. 20
				OUTER DIA: MAX. 105 MIN. 20
				WIDTH : MAX. 0 MIN. 0
OPERATING CONDITIONS				
RUNNING ACCURACY : 3	RUNNING QUIETNESS: 3	0	-> UNDESIRABLE:	
SELF ALIGN. CAPABILITY: 4	LOW FRICTION : 3	1	-> USUAL :	
RADIAL RIGIDITY : 1	MAINTENANCE EASE : 1	3	-> DESIRABLE :	
AXIAL RIGIDITY : 1	COST : 1	4	-> CRITICAL :	

PRESS ANY KEY TO CONTINUE

Figure 4.21: Screen printout of Input for Example 4

4.4.2 Outputs

The system suggests the deep groove ball bearings 4204 B.TVH (FAG) and 6404 (SKF), as most suitable bearings. The screen printouts of various system outputs are shown in Figures 4.22 to 4.26 respectively.

4.4.3 Discussions

As self aligning capability is critical and cost, running accuracy, and low friction are important the system ranks the deep groove ball bearing (single row) at first place (see Table 2.3). Minimum shaft diameter determines the optimum bearing size.

4.5 Example 5 : Bearing selection for a crane run-wheel

This example describes the selection of bearing for a runwheel of a steel mill crane which travels on its rails with four runwheels (courtesy: [14], pp 356-360).

4.5.1 Inputs

The following data are available for the bearing calculation :

RESULTS AND DISCUSSIONS

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT															
<div style="border: 1px solid black; padding: 5px;"> Input File <hr/> Bearing Type <hr/> BEARINGS BASED ON Load Ratings + Speed (rpm) + Dimensional limits <hr/> Save </div> <div style="margin-top: 20px;"> B E A R E S A E R S E L </div>	<div style="text-align: center; border-bottom: 1px solid black;"> SUITABLE BEARING TYPES </div> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr> <th style="width: 40%;">BEARNAME</th> <th style="width: 20%;">DBNAME</th> <th style="width: 40%;">WEIGHTAGE</th> </tr> </thead> <tbody> <tr> <td>DEEP GROOVE BALL(1)</td> <td>DGBB1</td> <td style="text-align: right;">62</td> </tr> <tr> <td>SPHERICAL ROLLER</td> <td>SRB1</td> <td style="text-align: right;">53</td> </tr> <tr> <td>SELF ALIGNING BALL</td> <td>SABB</td> <td style="text-align: right;">49</td> </tr> <tr> <td>BARREL ROLLER</td> <td>BRB</td> <td style="text-align: right;">46</td> </tr> </tbody> </table> <p style="text-align: center; margin-top: 10px;">(More weightage value indicates higher priority)</p> <p style="text-align: center;">PLEASE SELECT ONE BEARING TYPE</p>					BEARNAME	DBNAME	WEIGHTAGE	DEEP GROOVE BALL(1)	DGBB1	62	SPHERICAL ROLLER	SRB1	53	SELF ALIGNING BALL	SABB	49	BARREL ROLLER	BRB	46
BEARNAME	DBNAME	WEIGHTAGE																		
DEEP GROOVE BALL(1)	DGBB1	62																		
SPHERICAL ROLLER	SRB1	53																		
SELF ALIGNING BALL	SABB	49																		
BARREL ROLLER	BRB	46																		

keys and PRESS <Esc>

Figure 4.22: Screen printout of suitable bearing types for Example 4

FINALLY SELECTED SUITABLE BEARINGS									
B_NUMBER	COMPANY	BORE_DIA	OUTER_DIA	WIDTH	C	CO	RPM_OIL	RPM_GRES	
4204B.TVH	FAG	20	47	18	18000	11000	14000	10000	
6404	SKF	20	72	19	23600	16600	13000	10000	
4304B.TVH	FAG	20	52	21	23200	13700	13000	9500	
6305	SKF	25	62	17	17300	11400	14000	11000	
4205B.TVH	FAG	25	52	18	19300	12700	12000	9000	
6405	SKF	25	80	21	27500	19600	11000	9000	
4305B.TVH	FAG	25	62	24	31500	19300	10000	8500	

B_NUMBER : Bearing Number
 C : Dynamic Load Rating(Newtons)
 CO : Static Load Rating(Newtons)
 RPM_* : Limiting Speeds(rpm)
 MASS : Weight of bearing(g)
 Linear Dimensions are in m.m.

PRESS [ESC] TO CONTINUE FURTHER

Use keys to see all BEARINGS and SPECIFICATIONS

Figure 4.23: Screen printout of finally selected bearings for Example 4

RESULTS AND DISCUSSIONS

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT										
<div style="border: 1px solid black; padding: 5px;"> Output File ----- Seals Lubrication Fits & Tolerances </div> <div style="margin-top: 20px;"> B E A R ■ E S A E R S E L </div>	SEALS & SHIELDS Bearing Number : 4204B.TVH <div style="border: 1px solid black; padding: 10px; margin: 10px auto; width: 80%;"> <div style="text-align: center; border-bottom: 1px solid black; margin-bottom: 5px;">BEARING AVAILABILITY</div> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 70%;">WITH (Integral)</td> <td style="text-align: right;">STATUS</td> </tr> <tr> <td>SINGLE SEAL</td> <td style="text-align: right;">No</td> </tr> <tr> <td>DOUBLE SEALS</td> <td style="text-align: right;">No</td> </tr> <tr> <td>SINGLE SHIELD</td> <td style="text-align: right;">No</td> </tr> <tr> <td>DOUBLE SHIELDS</td> <td style="text-align: right;">No</td> </tr> </table> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> NOTE : To select SEALS for UNSEALED BEARINGS PRESS key F2 </div> </div> <div style="text-align: center; margin-top: 10px;"> press any key to continue </div>					WITH (Integral)	STATUS	SINGLE SEAL	No	DOUBLE SEALS	No	SINGLE SHIELD	No	DOUBLE SHIELDS	No
WITH (Integral)	STATUS														
SINGLE SEAL	No														
DOUBLE SEALS	No														
SINGLE SHIELD	No														
DOUBLE SHIELDS	No														

Recommendations for bearing INSTALLATION

Figure 4.24: Screen printout of recommendations for seals for Example 4

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT															
<div style="border: 1px solid black; padding: 5px;"> Output File ----- Seals Lubrication Fits & Tolerances </div> <div style="margin-top: 20px;"> B E A R ■ E S A E R S E L </div>	LUBRICATION DETAILS Bearing Number : 4204B.TVH <div style="border: 1px solid black; padding: 10px; margin: 10px auto; width: 80%;"> <div style="text-align: center; border-bottom: 1px solid black; margin-bottom: 5px;">SPECIFICATIONS</div> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 60%;">LUBRICANT</td> <td style="width: 10%;">:</td> <td style="width: 30%;">GREASE</td> </tr> <tr> <td>GREASE CODE</td> <td>:</td> <td>C-XG-271</td> </tr> <tr> <td>QUANTITY REQD. (g)</td> <td>:</td> <td>4.23</td> </tr> <tr> <td>REGREASE PERIOD(Hrs)</td> <td>:</td> <td>49691.86</td> </tr> <tr> <td>NLGI No</td> <td>:</td> <td>2 OR 3</td> </tr> </table> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> ADVICE : Fill grease upto 30-50 % of free space Over packing may cause over heating </div> <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> NOTE : For GREASE CODE description press F2 Press any key to continue </div> </div>					LUBRICANT	:	GREASE	GREASE CODE	:	C-XG-271	QUANTITY REQD. (g)	:	4.23	REGREASE PERIOD(Hrs)	:	49691.86	NLGI No	:	2 OR 3
LUBRICANT	:	GREASE																		
GREASE CODE	:	C-XG-271																		
QUANTITY REQD. (g)	:	4.23																		
REGREASE PERIOD(Hrs)	:	49691.86																		
NLGI No	:	2 OR 3																		

Recommendations for bearing INSTALLATION

Figure 4.25: Screen printout of recommendations for lubrication for Example 4

RESULTS AND DISCUSSIONS

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT																			
<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> Output File ----- Seals Lubrication Fits & Tolerances </div> <div style="display: flex; justify-content: space-between;"> B E A R ■ </div> <div style="display: flex; justify-content: space-between;"> E S </div> <div style="display: flex; justify-content: space-between;"> A E </div> <div style="display: flex; justify-content: space-between;"> R S E L </div>		<div style="text-align: center; border-bottom: 1px solid black; margin-bottom: 10px;"> ISO RECOMMENDED FITS AND TOLERANCES </div> <p>Bearing Number : 4204B.TVH</p> <div style="border: 1px solid black; padding: 10px; margin: 10px 0;"> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">PART</th> <th style="text-align: left;">FIT TYPE</th> <th style="text-align: left;">FIT</th> </tr> </thead> <tbody> <tr> <td>SHAFT</td> <td>:CLEARANCE FIT</td> <td>h6</td> </tr> <tr> <td>HOUSING</td> <td>:INTERFERENCE FIT</td> <td>M7</td> </tr> </tbody> </table> </div> <div style="border: 1px solid black; padding: 10px; margin: 10px 0;"> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">PART</th> <th style="text-align: left;">TOLERANCE(μm)</th> </tr> </thead> <tbody> <tr> <td>SHAFT DIAMETER</td> <td>0, -13</td> </tr> <tr> <td>HOUSING DIAMETER</td> <td>0, -25</td> </tr> <tr> <td>BEARING BORE DIA.</td> <td>0, -10</td> </tr> <tr> <td>BEARING OUTER DIA.</td> <td>0, -11</td> </tr> </tbody> </table> </div> <p style="text-align: center;">Press any key to continue</p>				PART	FIT TYPE	FIT	SHAFT	:CLEARANCE FIT	h6	HOUSING	:INTERFERENCE FIT	M7	PART	TOLERANCE(μm)	SHAFT DIAMETER	0, -13	HOUSING DIAMETER	0, -25	BEARING BORE DIA.	0, -10	BEARING OUTER DIA.	0, -11
PART	FIT TYPE	FIT																						
SHAFT	:CLEARANCE FIT	h6																						
HOUSING	:INTERFERENCE FIT	M7																						
PART	TOLERANCE(μm)																							
SHAFT DIAMETER	0, -13																							
HOUSING DIAMETER	0, -25																							
BEARING BORE DIA.	0, -10																							
BEARING OUTER DIA.	0, -11																							

Recommendations for bearing INSTALLATION

Figure 4.26: Screen printout of recommendations for fits for Example 4

Span	$a = 24 \text{ m}$
Weight of crane bridge	$G = 920 \text{ kN}$
Weight of travelling trolley	$K = 175 \text{ kN}$
Carrying capacity	$L = 245 \text{ kN}$
Travelling speed	$v = 2 \text{ m/s}$
Smallest distance between bearing and load with the trolley at extreme left/right position	$b = 1.8 \text{ m}$
Runwheel diameter	900 mm
Hub width	400 mm
Axle diameter	140 mm
Bearing center distance	250 mm

Fig. 4.27 shows the bearing load diagram. The loading depends on the position of the travelling trolley so load fluctuates from a maximum value to a minimum value. The calculated parameters are as follows :

Radial load	<i>Maximum : 212 kN; Minimum : 123 kN</i>
Axial load	36.5 kN
Sudden load	Negligible
Speed	43 min^{-1}

The input screen printout is shown in Fig. 4.28.

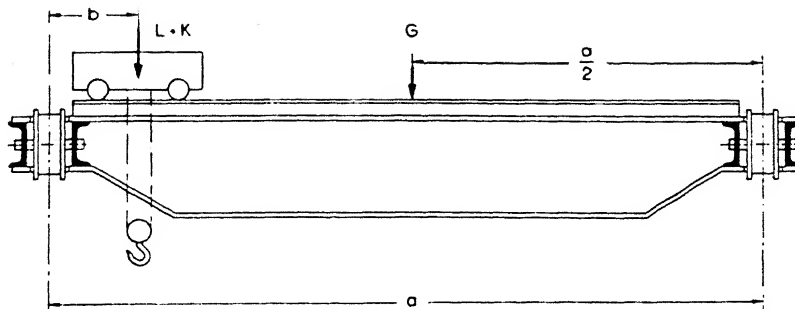


Figure 4.27: Load diagram for the steel mill crane

4.5.2 Outputs

The system suggests the spherical roller bearings 22328 C, as most suitable bearing. The screen printouts of various system outputs are shown in Figures 4.22 to 4.26 respectively.

INPUT DATA DISPLAY

SPEED (Constant) RPM VALUE 43	**RADIAL** Fluctuating MAXIMUM 212000 MINIMUM 123000	LOAD **THRUST** (Constant) VALUE 36500 DIRECTION Double **SUDDEN** Negligible	RELIABILITY RELIABILITY(%) : 90 LIFE OPERATING HRS : 12000 TEMPERATURE MAXIMUM TEMP. : 60 MINIMUM TEMP. : 30 DIMENSIONS BORE DIA.: MAX. 150 MIN. 140 OUTER DIA: MAX. 0 MIN. 0 WIDTH : MAX. 0 MIN. 0
---	--	--	---

OPERATING CONDITIONS			
RUNNING ACCURACY	: 1	RUNNING QUIETNESS:	1 0 -> UNDESIRABLE:
SELF ALIGN. CAPABILITY:	: 1	LOW FRICTION	: 1 1 -> USUAL :
RADIAL RIGIDITY	: 1	MAINTENANCE EASE	: 1 3 -> DESIRABLE :
AXIAL RIGIDITY	: 1	COST	: 1 4 -> CRITICAL :

PRESS ANY KEY TO CONTINUE

Figure 4.28: Screen printout of Input for Example 5

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
-----------------	-----------	--------------	--------	-------	------

Input File

Bearing Type

BEARINGS BASED ON

Load Ratings

+ Speed (rpm)

+ Dimensional limits

Save

SUITABLE BEARING TYPES

BEARNAME	DBNAME	WEIGHTAGE
DEEP GROOVE BALL(1)	DGBB1	29
ANGULAR CONT.BALL(2)	ACBB2	28
ANGULAR CONT.BALL(3)	ACBB3	28
SPHERICAL ROLLER	SRB1	27
BARREL ROLLER	BRB	22
SELF ALIGNING BALL	SABB	21
NEEDLE ROLLER(4)	NRB4	19

(More weightage value indicates higher priority)

PLEASE SELECT ONE BEARING TYPE

B E A R

E S

A E

R S E L

keys and PRESS <Esc>

Figure 4.29: Screen printout of suitable bearing types for Example 5

FINALLY SELECTED SUITABLE BEARINGS								
B_NUMBER	COMPANY	BORE_DIA	OUTER_DIA	WIDTH	C	CO	RPM_OIL	RPM_GR
22328C	SKF	140	300	102	980000	915000	1500	1100
23230C	SKF	150	270	96	815000	830000	1300	950
22330C	SKF	150	320	108	1120000	1040000	1400	1000

B_NUMBER : Bearing Number
 C : Dynamic Load Rating(Newtons)
 CO : Static Load Rating(Newtons)
 RPM * : Limiting Speeds(rpm)
 MASS : Weight of bearing(g)
 Linear Dimensions are in m.m.

PRESS [ESC] TO CONTINUE FURTHER
 Use keys to see all BEARINGS and SPECIFICATIONS

Figure 4.30: Screen printout of finally selected bearings for Example 5

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
-----------------	-----------	--------------	--------	-------	------

Output File

Seals
Lubrication
Fits & Tolerances

SEALS & SHIELDS
.....

Bearing Number : 22328C

BEARING AVAILABILITY

WITH (Integral)	STATUS
SINGLE SEAL	No
DOUBLE SEALS	No
SINGLE SHIELD	No
DOUBLE SHIELDS	No

NOTE : To select SEALS for UNSEALED BEARINGS
PRESS key F2

press any key to continue

Recommendations for bearing INSTALLATION

Figure 4.31: Screen printout of recommendations for seals for Example 5

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT										
<div style="border: 1px solid black; padding: 5px;"> Output File ----- Seals Lubrication Fits & Tolerances </div>	LUBRICATION DETAILS														
Bearing Number : 22328C															
SPECIFICATIONS															
<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 60%;">LUBRICANT</td> <td style="width: 40%;">GREASE</td> </tr> <tr> <td>GREASE CODE</td> <td>L-XG-274</td> </tr> <tr> <td>QUANTITY REQD. (g)</td> <td>153</td> </tr> <tr> <td>REGREASE PERIOD(Hrs)</td> <td>26956.65</td> </tr> <tr> <td>NLGI No</td> <td>2 OR 3</td> </tr> </table>						LUBRICANT	GREASE	GREASE CODE	L-XG-274	QUANTITY REQD. (g)	153	REGREASE PERIOD(Hrs)	26956.65	NLGI No	2 OR 3
LUBRICANT	GREASE														
GREASE CODE	L-XG-274														
QUANTITY REQD. (g)	153														
REGREASE PERIOD(Hrs)	26956.65														
NLGI No	2 OR 3														
<div style="border: 1px solid black; padding: 5px; margin: 5px 0;"> ADVICE : Fill grease upto 30-50 % of free space Over packing may cause over heating </div>															
<div style="border: 1px solid black; padding: 5px; margin: 5px 0;"> NOTE : For GREASE CODE description press F2 Press any key to continue </div>															
Recommendations for bearing INSTALLATION															

Figure 4.32: Screen printout of recommendations for lubrication for Example 5

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT										
<div style="border: 1px solid black; padding: 5px;"> Output File ----- Seals Lubrication Fits & Tolerances </div>	ISO RECOMMENDED FITS AND TOLERANCES														
Bearing Number : 22328C															
FITS															
<table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 30%;">PART</th> <th style="width: 30%;">FIT TYPE</th> <th style="width: 40%;">FIT</th> </tr> <tr> <td>SHAFT</td> <td>CLEARANCE FIT</td> <td>h6</td> </tr> <tr> <td>HOUSING</td> <td>INTERFERENCE FIT</td> <td>N7</td> </tr> </table>						PART	FIT TYPE	FIT	SHAFT	CLEARANCE FIT	h6	HOUSING	INTERFERENCE FIT	N7	
PART	FIT TYPE	FIT													
SHAFT	CLEARANCE FIT	h6													
HOUSING	INTERFERENCE FIT	N7													
TOLERANCES															
<table style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 50%;">PART</th> <th style="width: 50%;">TOLERANCE(μm)</th> </tr> <tr> <td>SHAFT DIAMETER</td> <td>0,-25</td> </tr> <tr> <td>HOUSING DIAMETER</td> <td>-14,-60</td> </tr> <tr> <td>BEARING BORE DIA.</td> <td>0,-25</td> </tr> <tr> <td>BEARING OUTER DIA.</td> <td>0,-35</td> </tr> </table>						PART	TOLERANCE(μm)	SHAFT DIAMETER	0,-25	HOUSING DIAMETER	-14,-60	BEARING BORE DIA.	0,-25	BEARING OUTER DIA.	0,-35
PART	TOLERANCE(μm)														
SHAFT DIAMETER	0,-25														
HOUSING DIAMETER	-14,-60														
BEARING BORE DIA.	0,-25														
BEARING OUTER DIA.	0,-35														
Press any key to continue															
Recommendations for bearing INSTALLATION															

Figure 4.33: Screen printout of recommendations for fits for Example 5

Chapter 5

Conclusions and Suggestions for Future Work

5.1 conclusions

- In recent years, a number of researchers have tried to develop expert system/software which are useful in the selection of mechanical components. Computer aided selection is still a partially solved problem. This is probably because of the large degree of subjectivity involved in the process and lack of mathematical tools.
- In the present work an attempt has been made to develop a knowledge-based system, **BEARSEL**, for the selection of antifriction bearings along with the selection of sealing and lubrication methods, and fits and tolerances. This system has been developed for most of the bearing applications.
- Instead of restricting the user with a single result, several alternative bearings are suggested by the system and the user is enabled to select the most suitable one by using preference and peculiarities of the situation.
- The system is exhaustive and is easy to use. It uses the bearing databases generated by including bearings of leading manufacturers. The database can also be updated to include the new developments.
- It is hoped that **BEARSEL** will find acceptability among the designers and practising engineers of the industries, and will be a useful module in the development of a general computer aided design programme.

5.2 Scope for future work

In its present stage, **BEARSEL** performs well as a knowledge based system for the selection of antifriction bearings for general applications. However, **BEARSEL** is limited in a number of ways and there are several natural steps to take in order to improve the system.

More knowledge

More knowledge is needed to be incorporated to increase the viability of the system. More and more bearing data from different bearing manufacturers should be included. Bearing types like Spherical plain bearings, may also be included.

More functionality

More recommendations for expert issues like clearance, mounting, sealing and lubrication should be included.

Integration with other software

It is felt that integration with analysis programs and other software is best done through a modern system architecture where workstations and mainframes are connected through a local area network. The necessary programs might then be run on the workstations after necessary changes.

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Appendix A

Screen Printouts of BEARSEL

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Data ----- Save	<div>OPERATING SPEED FOR BEARING</div> <div>TYPE Constant Variable</div> <div>RPM VALUE 0</div>				

Enter the constant bearing speed

Screen printout of input speed (constant) data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Data ----- Save	OPERATING SPEED FOR BEARING				
<div style="border: 1px solid black; padding: 5px; display: inline-block; margin-bottom: 10px;"> TYPE Constant Variable </div> <div style="border: 1px solid black; padding: 10px;"> <p>* NUMBER OF RPM STEPS 2</p> <p>* RPM FOR STEP 1 0</p> <p>* PERCENTAGE OF TOTAL/CYCLE TIME FOR ABOVE RPM STEP 0</p> </div>					
<div style="display: flex; justify-content: space-between;"> B E A R E S </div> <div style="display: flex; justify-content: space-between;"> A E R S E L </div>					

Enter bearing speed

Screen printout of input speed (variable) data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Data ----- Save	LOADS ACTING ON BEARING				
<div style="display: flex; justify-content: space-between;"> <div style="border: 1px solid black; padding: 5px; display: inline-block; margin-bottom: 10px;"> TYPE Radial Thrust Sudden Exit </div> <div style="border: 1px solid black; padding: 5px; display: inline-block; margin-bottom: 10px;"> MAGNITUDE Negligible Constant Variable </div> </div> <div style="border: 1px solid black; padding: 10px; margin-top: 10px;"> <p>LOAD VALUE (Newtons) 0</p> </div>					
<div style="display: flex; justify-content: space-between;"> B E A R E S </div> <div style="display: flex; justify-content: space-between;"> A E R S E L </div>					

Enter constant radial load value

Screen printout of input load (constant magnitude) data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Date ----- Save	LOADS ACTING ON BEARING <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="border: 1px solid black; padding: 5px; width: 20%;"> TYPE Radial Thrust Sudden Exit </div> <div style="border: 1px solid black; padding: 5px; width: 20%;"> MAGNITUDE Negligible Constant Variable </div> <div style="border: 1px solid black; padding: 5px; width: 40%;"> NATURE STEP Load (OR approximated) FLUCTUATING Load 1 CONSTANT + 1 ROTARY Loads OTHER Undefined Forms </div> </div> <div style="margin-top: 20px; border: 1px solid black; padding: 10px;"> <p>* NUMBER OF LOAD STEPS 2</p> <p>* LOAD (Newtons) FOR STEP 1 0</p> <p>* PERCENTAGE OF TOTAL/CYCLE TIME FOR ABOVE LOAD STEP 0</p> </div>				

Enter the load value

Screen printout of input load (variable of step nature) data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Date ----- Save	LOADS ACTING ON BEARING <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="border: 1px solid black; padding: 5px; width: 20%;"> TYPE Radial Thrust Sudden Exit </div> <div style="border: 1px solid black; padding: 5px; width: 20%;"> MAGNITUDE Negligible Constant Variable </div> <div style="border: 1px solid black; padding: 5px; width: 40%;"> NATURE STEP Load (OR approximated) FLUCTUATING Load 1 CONSTANT + 1 ROTARY Loads OTHER Undefined Forms </div> </div> <div style="margin-top: 20px; border: 1px solid black; padding: 10px;"> <p>* MAXIMUM LOAD (Newtons) 0</p> <p>* MINIMUM LOAD (Newtons) 0</p> </div>				

Enter the maximum load value

Screen printout of input load (variable of fluctuating nature) data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT															
<div>Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Date ----- Save</div>	<div>LOADS ACTING ON BEARING</div> <table border="1"><thead><tr><th>TYPE</th><th>MAGNITUDE</th><th>NATURE</th></tr></thead><tbody><tr><td>Radial</td><td>Negligible</td><td>STEP Load (OR approximated)</td></tr><tr><td>Thrust</td><td>Constant</td><td>FLUCTUATING Load</td></tr><tr><td>Sudden</td><td>Variable</td><td>1 CONSTANT + 1 ROTARY Loads</td></tr><tr><td></td><td></td><td>OTHER Undefined Forms</td></tr></tbody></table> <div>* CONSTANT LOAD (Newtons) 0</div> <div>* ROTARY LOAD (Newtons) 0</div>					TYPE	MAGNITUDE	NATURE	Radial	Negligible	STEP Load (OR approximated)	Thrust	Constant	FLUCTUATING Load	Sudden	Variable	1 CONSTANT + 1 ROTARY Loads			OTHER Undefined Forms
TYPE	MAGNITUDE	NATURE																		
Radial	Negligible	STEP Load (OR approximated)																		
Thrust	Constant	FLUCTUATING Load																		
Sudden	Variable	1 CONSTANT + 1 ROTARY Loads																		
		OTHER Undefined Forms																		

Enter the constant load value

Screen printout of input load (variable of stationary cum rotary nature) data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT															
<div>Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Date ----- Save</div>	<div>LOADS ACTING ON BEARING</div> <table border="1"><thead><tr><th>TYPE</th><th>MAGNITUDE</th><th>NATURE</th></tr></thead><tbody><tr><td>Radial</td><td>Negligible</td><td>STEP Load (OR approximated)</td></tr><tr><td>Thrust</td><td>Constant</td><td>FLUCTUATING Load</td></tr><tr><td>Sudden</td><td>Variable</td><td>1 CONSTANT + 1 ROTARY Loads</td></tr><tr><td></td><td></td><td>OTHER Undefined Forms</td></tr></tbody></table> <div>* MEAN/EQUIVELENT CONSTANT LOAD(Newtons) 0</div>					TYPE	MAGNITUDE	NATURE	Radial	Negligible	STEP Load (OR approximated)	Thrust	Constant	FLUCTUATING Load	Sudden	Variable	1 CONSTANT + 1 ROTARY Loads			OTHER Undefined Forms
TYPE	MAGNITUDE	NATURE																		
Radial	Negligible	STEP Load (OR approximated)																		
Thrust	Constant	FLUCTUATING Load																		
Sudden	Variable	1 CONSTANT + 1 ROTARY Loads																		
		OTHER Undefined Forms																		

Enter the mean/equivalent load value

Screen printout of input load (variable of undefined forms) data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT																			
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Date ----- Save B E A R E S A E R S E L	LOADS ACTING ON BEARING <table border="1"> <thead> <tr> <th>TYPE</th> <th>MAGNITUDE</th> <th>NATURE</th> </tr> </thead> <tbody> <tr> <td>Radial</td> <td>Negligible</td> <td>STEP Load (OR approximated)</td> </tr> <tr> <td>Thrust</td> <td>Constant</td> <td>FLUCTUATING Load</td> </tr> <tr> <td>Sudden</td> <td>Variable</td> <td>1 CONSTANT + 1 ROTARY Loads</td> </tr> <tr> <td>Exit</td> <td></td> <td>OTHER Undefined Forms</td> </tr> </tbody> </table> <table border="1"> <tbody> <tr> <td>* CONSTANT LOAD (Newtons)</td> <td>0</td> </tr> <tr> <td>* ROTARY LOAD (Newtons)</td> <td>0</td> </tr> </tbody> </table>					TYPE	MAGNITUDE	NATURE	Radial	Negligible	STEP Load (OR approximated)	Thrust	Constant	FLUCTUATING Load	Sudden	Variable	1 CONSTANT + 1 ROTARY Loads	Exit		OTHER Undefined Forms	* CONSTANT LOAD (Newtons)	0	* ROTARY LOAD (Newtons)	0
TYPE	MAGNITUDE	NATURE																						
Radial	Negligible	STEP Load (OR approximated)																						
Thrust	Constant	FLUCTUATING Load																						
Sudden	Variable	1 CONSTANT + 1 ROTARY Loads																						
Exit		OTHER Undefined Forms																						
* CONSTANT LOAD (Newtons)	0																							
* ROTARY LOAD (Newtons)	0																							

Enter the constant load value

Screen printout of input load (variable of stationary cum rotary nature) data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT																	
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Date ----- Save B E A R E S A E R S E L	LOADS ACTING ON BEARING <table border="1"> <thead> <tr> <th>TYPE</th> <th>MAGNITUDE</th> <th>NATURE</th> </tr> </thead> <tbody> <tr> <td>Radial</td> <td>Negligible</td> <td>STEP Load (OR approximated)</td> </tr> <tr> <td>Thrust</td> <td>Constant</td> <td>FLUCTUATING Load</td> </tr> <tr> <td>Sudden</td> <td>Variable</td> <td>1 CONSTANT + 1 ROTARY Loads</td> </tr> <tr> <td>Exit</td> <td></td> <td>OTHER Undefined Forms</td> </tr> </tbody> </table> <table border="1"> <tbody> <tr> <td>* MEAN/EQUIVELENT CONSTANT LOAD(Newtons)</td> <td>0</td> </tr> </tbody> </table>					TYPE	MAGNITUDE	NATURE	Radial	Negligible	STEP Load (OR approximated)	Thrust	Constant	FLUCTUATING Load	Sudden	Variable	1 CONSTANT + 1 ROTARY Loads	Exit		OTHER Undefined Forms	* MEAN/EQUIVELENT CONSTANT LOAD(Newtons)	0
TYPE	MAGNITUDE	NATURE																				
Radial	Negligible	STEP Load (OR approximated)																				
Thrust	Constant	FLUCTUATING Load																				
Sudden	Variable	1 CONSTANT + 1 ROTARY Loads																				
Exit		OTHER Undefined Forms																				
* MEAN/EQUIVELENT CONSTANT LOAD(Newtons)	0																					

Enter the mean/equivalent load value

Screen printout of input load (variable of undefined forms) data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Data ----- Save	<div style="text-align: center; border-bottom: 1px solid black; margin-bottom: 10px;">LOADS ACTING ON BEARING ■</div> <div style="border: 1px solid black; padding: 10px; margin: 10px auto; width: 80%;"> <div style="text-align: center; margin-bottom: 10px;">RADIAL LOAD DIRECTION</div> <div style="display: flex; justify-content: space-around;"> CONSTANT ROTATING INDETERMINATE </div> </div>				

B E A R ■
 E S
 A E
 R S E L

Enter the nature of radial load DIRECTION

Screen printout of input load (radial load direction) data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Data ----- Save	<div style="text-align: center; border-bottom: 1px solid black; margin-bottom: 10px;">LOADS ACTING ON BEARING ■</div> <div style="border: 1px solid black; padding: 10px; margin: 10px auto; width: 80%;"> <div style="text-align: center; margin-bottom: 10px;">THRUST LOAD DIRECTION</div> <div style="display: flex; justify-content: space-around;"> SINGLE DOUBLE </div> </div>				

B E A R ■
 E S
 A E
 R S E L

Enter the DIRECTION with which thrust load is acting

Screen printout of input load (thrust load direction) data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Data ----- Save	LOADS ACTING ON BEARING				
	TYPE Kadial Thrust Sudden ----- Exit	Negligible With LIGHT shock With MEDIUM shock With HEAVY shock ----- Help			
	<div style="border: 1px solid black; height: 100px; width: 100%;"></div>				
B E A R S E S A E R S E L					

Select sudden LOAD TYPE or HELP to select for different application

Screen printout of input load (sudden) data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Data ----- Save	LOADS ACTING ON BEARING				
	USE				DUTY_TYPE
	GENERAL PUPPOSE CHAIN AND GEAR DRIVES COAL, SAND AND ORE CONVEYORS ROTARY COMPRESSORS ELECTRIC MOTORS (AUTO PINIONS, FRONT WHEELS, REAR WHEELS AND TRANSMISSIONS WITH INDEPEDENT SUSPENSION) FARM MACHINARIES ; ENGINES HOUSEHOLD APPLIANCES				ALMOST NO SUDDEN LOAD
	FANS ; CENTRIFUGAL BLOWERS MIXERS CONTINUOUSLY OPRATED CRANES BELT TENSION DEVICES APPLICATION WITH DEADWEIGHT AS PRINCIPAL LOAD GROUND GEARS				LIGHT SHOCK SERVICE

Press <Esc> to EXIT Help

Screen printout of help display for sudden load

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Data ----- Save	REQUIRED BEARING RELIABILITY <input type="checkbox"/>				
RELIABILITY (%) 90					

B E A R ☐
 E S ☐
 A E ☐
 R S E L ☐

Please enter the reliability if desired more than 90 %

Screen printout of input reliability data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Data ----- Save	REQUIRED SERVICE LIFE FOR BEARING <input type="checkbox"/>				
<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> BEARING APPLICATION General Applications Rail/Road Applications ----- Help </div> <div style="border: 1px solid black; padding: 10px; min-height: 100px;"> LIFE VALUE (Operating Hours) 0 </div>					

B E A R ☐
 E S ☐
 A E ☐
 R S E L ☐

Please enter the required service life

Screen printout of input service life (general applications) data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Date ----- Save	<div style="text-align: center;">REQUIRED SERVICE LIFE FOR BEARING</div> <div style="border: 1px solid black; padding: 5px; margin: 10px 0;"> BEARING APPLICATION General Applications Rail/Road Applications ----- Help </div> <div style="border: 1px solid black; padding: 10px; margin: 10px 0;"> <div style="display: flex; justify-content: space-between;"> <div>LIFE VALUE (Millions of running kms)</div> <div>0.00</div> </div> <div style="display: flex; justify-content: space-between;"> <div>WHEEL DIAMETER (Meters)</div> <div>0.00</div> </div> </div>				

Please enter the required service life

Screen printout of input service life (rail/road applications) data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Date ----- Save	<div style="text-align: center;">OPERATING TEMPERATURE RANGE FOR BEARING</div> <div style="border: 1px solid black; padding: 10px; margin: 10px 0;"> <div style="display: flex; justify-content: space-between;"> <div>MAXIMUM OPERATING TEMPERATURE (°C)</div> <div>0</div> </div> <div style="display: flex; justify-content: space-between;"> <div>MINIMUM OPERATING TEMPERATURE (°C)</div> <div>0</div> </div> </div>				

Enter maximum temperature for the bearing

Screen printout of input operating temperature data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT												
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Data ----- Save	REQUIRED DIMENSIONAL LIMITS FOR BEARING <hr style="border: 1px solid black;"/> <div style="border: 1px solid black; padding: 10px; margin: 10px auto; width: 80%;"> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 80%;">* ENTER MAXIMUM BORE/SHAFT DIAMETER (mm)</td> <td style="width: 20%; text-align: right;">0</td> </tr> <tr> <td>ENTER MINIMUM BORE/SHAFT DIAMETER (mm)</td> <td style="text-align: right;">0</td> </tr> <tr> <td>* ENTER MAXIMUM OUTER/HOUSING DIAMETER (mm)</td> <td style="text-align: right;">0</td> </tr> <tr> <td>ENTER MINIMUM OUTER/HOUSING DIAMETER (mm)</td> <td style="text-align: right;">0</td> </tr> <tr> <td>* ENTER MAXIMUM WIDTH (mm)</td> <td style="text-align: right;">0</td> </tr> <tr> <td>ENTER MINIMUM WIDTH (mm)</td> <td style="text-align: right;">0</td> </tr> </table> </div>					* ENTER MAXIMUM BORE/SHAFT DIAMETER (mm)	0	ENTER MINIMUM BORE/SHAFT DIAMETER (mm)	0	* ENTER MAXIMUM OUTER/HOUSING DIAMETER (mm)	0	ENTER MINIMUM OUTER/HOUSING DIAMETER (mm)	0	* ENTER MAXIMUM WIDTH (mm)	0	ENTER MINIMUM WIDTH (mm)	0
* ENTER MAXIMUM BORE/SHAFT DIAMETER (mm)	0																
ENTER MINIMUM BORE/SHAFT DIAMETER (mm)	0																
* ENTER MAXIMUM OUTER/HOUSING DIAMETER (mm)	0																
ENTER MINIMUM OUTER/HOUSING DIAMETER (mm)	0																
* ENTER MAXIMUM WIDTH (mm)	0																
ENTER MINIMUM WIDTH (mm)	0																
<div style="display: flex; justify-content: space-between;"> B E A R ■ </div> <div style="display: flex; justify-content: space-between;"> E S </div> <div style="display: flex; justify-content: space-between;"> A E </div> <div style="display: flex; justify-content: space-between;"> R S E L </div>																	

Enter 2000 if not interested in specifying

Screen printout of input dimensions data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Data ----- Save	<div style="display: flex; justify-content: space-around;"> <div style="border: 1px solid black; padding: 5px; text-align: left;"> ROTATING PART Shaft Housing Both </div> <div style="border: 1px solid black; padding: 5px; text-align: left;"> BEARING FUNCTION Locating Cross Locating Non Locating </div> </div> <div style="border: 1px solid black; height: 150px; margin-top: 10px; width: 100%;"></div>				
<div style="display: flex; justify-content: space-between;"> B E A R ■ </div> <div style="display: flex; justify-content: space-between;"> E S </div> <div style="display: flex; justify-content: space-between;"> A E </div> <div style="display: flex; justify-content: space-between;"> R S E L </div>					

Select the bearing function and press < Enter >

Screen printout of input operating conditions

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT				
Speed Load Reliability Service Life Temperature Dimensions Operating Conditions ----- Display Data ----- Save	PLEASE ENTER THE DESIRED LEVEL FOR ALL OPERATING CONDITIONS _____								
	<table style="width: 100%; border: none;"> <tr> <td style="text-align: center; border-bottom: 1px solid black;">OPERATING CONDITIONS</td> <td style="text-align: center; border-bottom: 1px solid black;">DESIRED LEVEL</td> </tr> <tr> <td style="border: 1px solid black; padding: 5px; vertical-align: top;"> Running Accuracy Self Alignment Capability Radial Rigidity Axial Rigidity Running Quietness Low Friction Maintenance Cost EXIT TO MAIN MENU </td> <td style="border: 1px solid black; padding: 5px; text-align: center; vertical-align: middle;"> Critical Important Usual Undesirable </td> </tr> </table>					OPERATING CONDITIONS	DESIRED LEVEL	Running Accuracy Self Alignment Capability Radial Rigidity Axial Rigidity Running Quietness Low Friction Maintenance Cost EXIT TO MAIN MENU	Critical Important Usual Undesirable
OPERATING CONDITIONS	DESIRED LEVEL								
Running Accuracy Self Alignment Capability Radial Rigidity Axial Rigidity Running Quietness Low Friction Maintenance Cost EXIT TO MAIN MENU	Critical Important Usual Undesirable								
B E A R E S A E R S E L									

Select desired level of OPERATING CONDITION and press < Enter >

Screen printout of input operating conditions (contd ...)

INPUT DATA DISPLAY

SELECT THE INPUT FILE FOR DATA DISPLAY :	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="text-align: left;">IPNAME</th> </tr> <tr> <td>CURRENT</td> </tr> <tr><td>EX1</td></tr> <tr><td>EX2</td></tr> <tr><td>EX3</td></tr> <tr><td>EX4</td></tr> <tr><td>EX5</td></tr> <tr><td>EX6</td></tr> <tr><td>EX7</td></tr> <tr><td>EX8</td></tr> <tr><td>EX9</td></tr> <tr><td>EX10</td></tr> </table>	IPNAME	CURRENT	EX1	EX2	EX3	EX4	EX5	EX6	EX7	EX8	EX9	EX10
IPNAME													
CURRENT													
EX1													
EX2													
EX3													
EX4													
EX5													
EX6													
EX7													
EX8													
EX9													
EX10													

The CURRENT is the name of INPUT FILE having currently entered data

Select the input file name (IPNAME) and press < Esc >

Screen printout of input data display (input file selection)

INPUT DATA DISPLAY

SPEED (Constant) RPM VALUE 3000	**RADIAL** (Constant) VALUE 2120	LOAD (Constant) VALUE 6000	**THRUST** DIRECTION Single **SUDDEN** Negligible	RELIABILITY RELIABILITY(%) : 90	LIFE OPERATING HRS : 40000
				TEMPERATURE MAXIMUM TEMP. : 70 MINIMUM TEMP. : 30	
				DIMENSIONS BORE DIA.: MAX. 80 MIN. 70 OUTER DIA: MAX. 0 MIN. 0 WIDTH : MAX. 0 MIN. 0	

OPERATING CONDITIONS			
RUNNING ACCURACY : 4	RUNNING QUIETNESS: 1	0 -> UNDESIRABLE:	
SELF ALIGN. CAPABILITY: 1	LOW FRICTION : 3	1 -> USUAL :	
RADIAL RIGIDITY : 3	MAINTENANCE EASE : 1	3 -> DESIRABLE :	
AXIAL RIGIDITY : 3	COST : 1	4 -> CRITICAL :	

PRESS ANY KEY TO CONTINUE

Screen printout of input data display (data display)

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
-----------------	-----------	--------------	--------	-------	------

Input File

 Bearing Type

 BEARINGS BASED ON
 Load Ratings
 + Speed (rpm)
 + Dimensional limits

 Save

INPUT FILE FOR BEARING SELECTION

SELECT INPUT FILE FOR BEARING SELECTION:

IPNAME
 CURRENT
 EX1
 EX2
 EX3
 EX4
 EX5
 EX6
 EX7
 EX8
 EX9

(CURRENT is the input file containing currently entered input data)

keys to see all names)

Screen printout of input file selection for bearing selection

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT												
<div style="border: 1px solid black; padding: 2px;"> Input File <hr/> Bearing Type <hr/> BEARINGS BASED ON Load Ratings + Speed (rpm) + Dimensional limits <hr/> Save </div>	SUITABLE BEARING TYPES <div style="border: 1px solid black; padding: 5px; margin: 5px auto; width: 80%;"> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">BEARNAME</th> <th style="text-align: left;">DBNAME</th> <th style="text-align: left;">WEIGHTAGE</th> </tr> </thead> <tbody> <tr> <td>ANGULAR CONT.BALL(2)</td> <td>ACBB2</td> <td>58</td> </tr> <tr> <td>ANGULAR CONT.BALL(3)</td> <td>ACBB3</td> <td>58</td> </tr> <tr> <td>DEEP GROOVE BALL(1)</td> <td>DGBB1</td> <td>57</td> </tr> </tbody> </table> </div> <p style="text-align: center; margin-top: 10px;">(More weightage value indicates higher priority)</p> <p style="text-align: center;">PLEASE SELECT ONE BEARING TYPE</p>					BEARNAME	DBNAME	WEIGHTAGE	ANGULAR CONT.BALL(2)	ACBB2	58	ANGULAR CONT.BALL(3)	ACBB3	58	DEEP GROOVE BALL(1)	DGBB1	57
BEARNAME	DBNAME	WEIGHTAGE															
ANGULAR CONT.BALL(2)	ACBB2	58															
ANGULAR CONT.BALL(3)	ACBB3	58															
DEEP GROOVE BALL(1)	DGBB1	57															
<div style="display: flex; justify-content: space-between;"> B E A R ■ </div> <div style="display: flex; justify-content: space-between;"> E S </div> <div style="display: flex; justify-content: space-between;"> A E </div> <div style="display: flex; justify-content: space-between;"> R S E L </div>																	

keys and PRESS <Esc>

Screen printout of suitable bearing types display

SUITABLE BEARINGS ACCORDING TO LOAD RATINGS									
B_NUMBER	COMPANY	BORE_DIA	OUTER_DIA	WIDTH	C	CO	RPM_OIL	RIM_GRES	M
7218BG	SKF	90	160	60	132000	150000	3400	2400	
7314BG	SKF	70	150	70	143000	143000	3800	2800	
7219BG	SKF	95	170	64	150000	173000	3200	2200	
7315BG	SKF	75	160	74	153000	160000	3600	2600	
7321B	SKF	105	225	49	156000	163000	3000	2200	
7220BG	SKF	100	180	68	163000	183000	3000	2000	
7316BG	SKF	80	170	78	166000	180000	3400	2400	
7317BG	SKF	85	180	82	180000	200000	3200	2200	
7222BG	SKF	110	200	76	190000	228000	2800	1900	

B_NUMBER : Bearing Number
 C : Dynamic Load Rating(Newtons)
 CO : Static Load Rating(Newtons)
 RPM_* : Limiting Speeds(rpm)
 MASS : Weight of bearing(g)
 Linear Dimensions are in m.m.

PRESS [ESC] TO CONTINUE FURTHER

Use keys to see all BEARINGS and SPECIFICATIONS

Screen printout of display of suitable bearings (based on load ratings)

SUITABLE BEARINGS ACCORDING TO LOAD RATING & RPM

B_NUMBER	COMPANY	BORE_DIA	OUTER_DIA	WIDTH	C	CO	RPM_OIL	RPM_GRES	M
7314BG	SKF	70	150	70	143000	143000	3800	2800	1
7315BG	SKF	75	160	74	153000	160000	3600	2600	
7316BG	SKF	80	170	78	166000	180000	3400	2400	
7317BG	SKF	85	180	82	180000	200000	3200	2200	
7218BG	SKF	90	160	60	132000	150000	3400	2400	
7318BG	SKF	90	190	86	193000	224000	3000	2000	
7219BG	SKF	95	170	64	150000	173000	3200	2200	
7220BG	SKF	100	180	68	163000	183000	3000	2000	
7321B	SKF	105	225	49	156000	163000	3000	2200	

B_NUMBER : Bearing Number
 C : Dynamic Load Rating(Newtons)
 CO : Static Load Rating(Newtons)
 RPM_* : Limiting Speeds(rpm)
 MASS : Weight of bearing(g)
 Linear Dimensions are in m.m.

PRESS [ESC] TO CONTINUE FURTHER

Use keys to see all BEARINGS and SPECIFICATIONS

Screen printout of display of suitable bearings (load ratings + speed)

FINALLY SELECTED SUITABLE BEARINGS

B_NUMBER	COMPANY	BORE_DIA	OUTER_DIA	WIDTH	C	CO	RPM_OIL	RPM_GRES	M
7314BG	SKF	70	150	70	143000	143000	3800	2800	
7315BG	SKF	75	160	74	153000	160000	3600	2600	
7316BG	SKF	80	170	78	166000	180000	3400	2400	

B_NUMBER : Bearing Number
 C : Dynamic Load Rating(Newtons)
 CO : Static Load Rating(Newtons)
 RPM_* : Limiting Speeds(rpm)
 MASS : Weight of bearing(g)
 Linear Dimensions are in m.m.

PRESS [ESC] TO CONTINUE FURTHER

Use keys to see all BEARINGS and SPECIFICATIONS

Screen printout of display of suitable bearings (finally selected)

DATA-INPUT/EDIT SELECTION INSTALLATION UPDATE PRINT EXIT

Output File

Seals
Lubrication
Fits & Tolerances

BEARING INSTALLATION
.....

SELECT THE
OUTPUT FILE :

OPNAME	IPNAME	BTNAME
CURRENT	EX4	ACBB2
EX1_1	EX1	DGBB1
EX2_1	EX2	CRB1
EX3_1	EX3	ACBB2
EX3_2	EX3	CRB3
EX4_1	EX4	ACBB2
EX5_1	EX5	DGBB1
EX6_1	EX6	SRB1
EX7_1	EX7	SRB1

B E A R ■
E S
A E
R S E L

Select output file name (OPNAME) using keys & Press <Esc>

Screen printout of output file selection for bearing installation

DATA-INPUT/EDIT SELECTION INSTALLATION UPDATE PRINT EXIT

Output File

Seals
Lubrication
Fits & Tolerances

SEALS & SHIELDS
.....

Bearing Number : 7314BG

BEARING AVAILABILITY

WITH (Integral)	STATUS
SINGLE SEAL	No
DOUBLE SEALS	No
SINGLE SHIELD	No
DOUBLE SHIELDS	No

NOTE : To select SEALS for UNSEALED BEARINGS
PRESS key F2

press any key to continue

B E A R ■
E S
A E
R S E L

Recommendations for bearing INSTALLATION

Screen printout of recommendations for seals for bearing installation

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
-----------------	-----------	--------------	--------	-------	------

Output File

Seals
Lubrication
Fits & Tolerances

B E A R
E S
A E
R S E L

LUBRICATION DETAILS
.....

Bearing Number : 7314BG

SPECIFICATIONS

LUBRICANT : Oil
VISCOSITY(cst) : 14.79
VISCOSTY INDEX : Medium OR High

ADVICE :For centralised oil lubrication system
same oil may also be used for the bearing

Press any key to continue

Recommendations for bearing INSTALLATION

Screen printout of recommendations for bearing lubrication (oil)

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
-----------------	-----------	--------------	--------	-------	------

Output File

Seals
Lubrication
Fits & Tolerances

B E A R
E S
A E
R S E L

LUBRICATION DETAILS
.....

Bearing Number : 7314BG

SPECIFICATIONS

LUBRICANT : GREASE
GREASE CODE : L-XG-271
QUANTITY REQD. (g) : 52.50
REGREASE PERIOD(Hrs): 13933.20
NLGI No : 2 OR 3

ADVICE :Fill grease upto 30-50 % of free space
Over packing may cause over heating

NOTE : For GREASE CODE description press F2
Press any key to continue

Recommendations for bearing INSTALLATION

Screen printout of recommendations for bearing lubrication (grease)

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT																								
<div style="border: 1px solid black; padding: 5px;"> Output File ----- Seals Lubrication Fits & Tolerances </div>	ISO RECOMMENDED FITS AND TOLERANCES Bearing Number : 7314BG																												
<div style="border: 1px solid black; padding: 10px; margin: 10px auto; width: 80%;"> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="3" style="text-align: center; border-bottom: 1px solid black;">FITS</th> </tr> </thead> <tbody> <tr> <td style="width: 30%;">PART</td> <td style="width: 40%;">FIT TYPE</td> <td style="width: 30%;">FIT</td> </tr> <tr> <td>SHAFT</td> <td>: INTERFERENCE FIT</td> <td>j6</td> </tr> <tr> <td>HOUSING</td> <td>: CLEARANCE FIT</td> <td>H7</td> </tr> </tbody> </table> <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th colspan="2" style="text-align: center; border-bottom: 1px solid black;">TOLERANCES</th> </tr> </thead> <tbody> <tr> <td style="width: 60%;">PART</td> <td style="width: 40%;">TOLERANCE (μm)</td> </tr> <tr> <td>SHAFT DIAMETER</td> <td>+12, -7</td> </tr> <tr> <td>HOUSING DIAMETER</td> <td>0, +40</td> </tr> <tr> <td>BEARING BORE DIA.</td> <td>0, -15</td> </tr> <tr> <td>BEARING OUTER DIA.</td> <td>0, -18</td> </tr> </tbody> </table> </div>						FITS			PART	FIT TYPE	FIT	SHAFT	: INTERFERENCE FIT	j6	HOUSING	: CLEARANCE FIT	H7	TOLERANCES		PART	TOLERANCE (μm)	SHAFT DIAMETER	+12, -7	HOUSING DIAMETER	0, +40	BEARING BORE DIA.	0, -15	BEARING OUTER DIA.	0, -18
FITS																													
PART	FIT TYPE	FIT																											
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BEARING OUTER DIA.	0, -18																												
Press any key to continue																													

Recommendations for bearing INSTALLATION

Screen printout of recommendations for ISO fits and tolerances

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
<div style="border: 1px solid black; padding: 5px;"> DATA-BASE Add Edit View Delete </div>					

UPDATE bearing data-bases

Screen printout of update bearing databases

UPDATE BEARING DATA-BASE

SELECT THE BEARING DATABASE TO Add THE DATA

BEARNAME

ANGULAR CONT.BALL(1)

ANGULAR CONT.BALL(2)

ANGULAR CONT.BALL(3)

ANGU.CONT.THR.BALL(S.D.)

ANGU.CONT.THR.BALL(D.D.)

BARREL ROLLER

CLYNDRICAL ROLLER(1)

CLYNDRICAL ROLLER(3)

CLYNDRICAL ROLLER(5)

CLYNDR.ROLL.(DOUB.ROW)

CLYNDR.ROLL.THRUST

DEEP GROOVE BALL(1)

DEEP GROOVE BALL(2)

FOUR POINT CONT.BALL

MEGNETO

NEEDLE ROLLER(1)

Select the DATA-BASE name (BEARNAME) & Press <Esc> to continue

Screen printout of update bearing databases (database selection)

UPDATE BEARING DATA-BASE

TYPE	B_NUMBER	COMPANY	BORE_DIA	OUTER_DIA	WIDTH	C	CO	RPM_GRES	RPM_O
	123456	SKF							

(Use keys to SCROLL the DATA-BASE table)

B_NUMBER : Bearing Number

C : Dynamic Load Rating(Newtons)

CO : Static Load Rating(Newtons)

RPM_* : Limiting Speeds(rpm)

Linear Dimensions are in m.m.

Press F2 for ATTRIBUTE DESCRIPTION

Please enter all BEARING ATTRIBUTES & Press <Esc> to continue

Screen printout of update bearing databases (data entry)

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
Database Input Data Bearings Selected Others	<div style="border: 1px solid black; padding: 10px;"> <div style="display: flex; justify-content: space-between;"> <div> <p>SELECT THE BEARING DATABASE TO PRINT :</p> <p>BEARNAME</p> <p>ANGULAR CONT.BALL(1) ANGULAR CONT.BALL(2) ANGULAR CONT.BALL(3) ANGU.CONT.THR.BALL(S.D.) ANGU.CONT.THR.BALL(D.D.) BARREL ROLLER CLYNDRICAL ROLLER(1) CLYNDRICAL ROLLER(3) CLYNDRICAL ROLLER(5) CLYNDR.ROLL.(DOUB.ROW) CLYNDR.ROLL.THRUST DEEP GROOVE BALL(1) DEEP GROOVE BALL(2)</p> </div> </div> </div>				
B E A R E S A S R S E L					

Select the bearing data-base name(BEARNAME) with keys & Press <Esc>

Screen printout of printing bearing databases

INPUT-DATA File Name: EX3

SPEED : Constant
 RPM VALUE : 1300

RADIAL LOAD : Step Load ; # OF STEPS : 2
 LOAD VALUES : 6100, 6575,
 % OF CYCLE : 50, 50,
 THRUST LOAD : Constant ;
 LOAD VALUE : 800
 THRUST LOAD DIRECTION : Double
 SUDDEN LOAD : Medium Shock

RELIABILITY(%) : 90
 LIFE : RUNNING KMS(million) : 3.00 ; WHEEL DIA.(m) : 0.52
 TEMPERATURE :
 MAXIMUM TEMP. : 90
 MINIMUM TEMP. : 30

DIMENSIONS :	MAXIMUM	MINIMUM
BORE DIA. :	95	90
OUTER DIA. :	0	0
WIDTH :	0	0

OPERATING CONDITIONS :
 RUNNING ACCURACY : 4 ; RUNNING QUIETNESS: 1
 SELF ALIGN. CAPABILITY: 1 ; COST : 4
 RADIAL RIGIDITY : 3 ; MAINTENANCE EASE : 1
 AXIAL RIGIDITY : 1 ; LOW FRICTION : 1
 (0 -> Undesirable ; 1 -> USUAL ; 3 -> DESIRABLE ; 4 -> CRITICAL)

Screen printout of printing input data

DATA-INPUT/EDIT	SELECTION	INSTALLATION	UPDATE	PRINT	EXIT
<div>To Dot Prompt To DOS</div>					
<div>BEAR ■ E S A E RSEL</div>					
QUIT the system					

Screen printout of exit module

Appendix B

BEARSEL System Details

B.1 System Summary

This system has:

- 5008 lines of code
- 56 program files
- 1 procedure files
- 54 procedures and functions
- 61 databases
- 4 index files
- 1 report forms
- 0 format files
- 0 label forms
- 0 binary files
- 0 memory variable files
- 0 other files
- 427 cross-referenced tokens

```

INPUT.DBF (database)
TEMPDATA.DBF (database)
BIPBIP      (procedure in PROCED2.PRG)
IDSAVE.PRG
  INPUT.DBF (database)
  BIPBIP      (procedure in PROCED2.PRG)
  SAVED       (procedure in IDSAVE.PRG)
    INPUT.DBF (database)
    TEMPDATA.DBF (database)
    OUTPUT.DBF (database)
    TEMPSEL.DBF (database)
    &FNAME (database)
    BIPBIP      (procedure in PROCED2.PRG)
    SAVED       (procedure in IDSAVE.PRG)
      INPUT.DBF (database)
      TEMPDATA.DBF (database)
      OUTPUT.DBF (database)
      TEMPSEL.DBF (database)
      &FNAME (database)

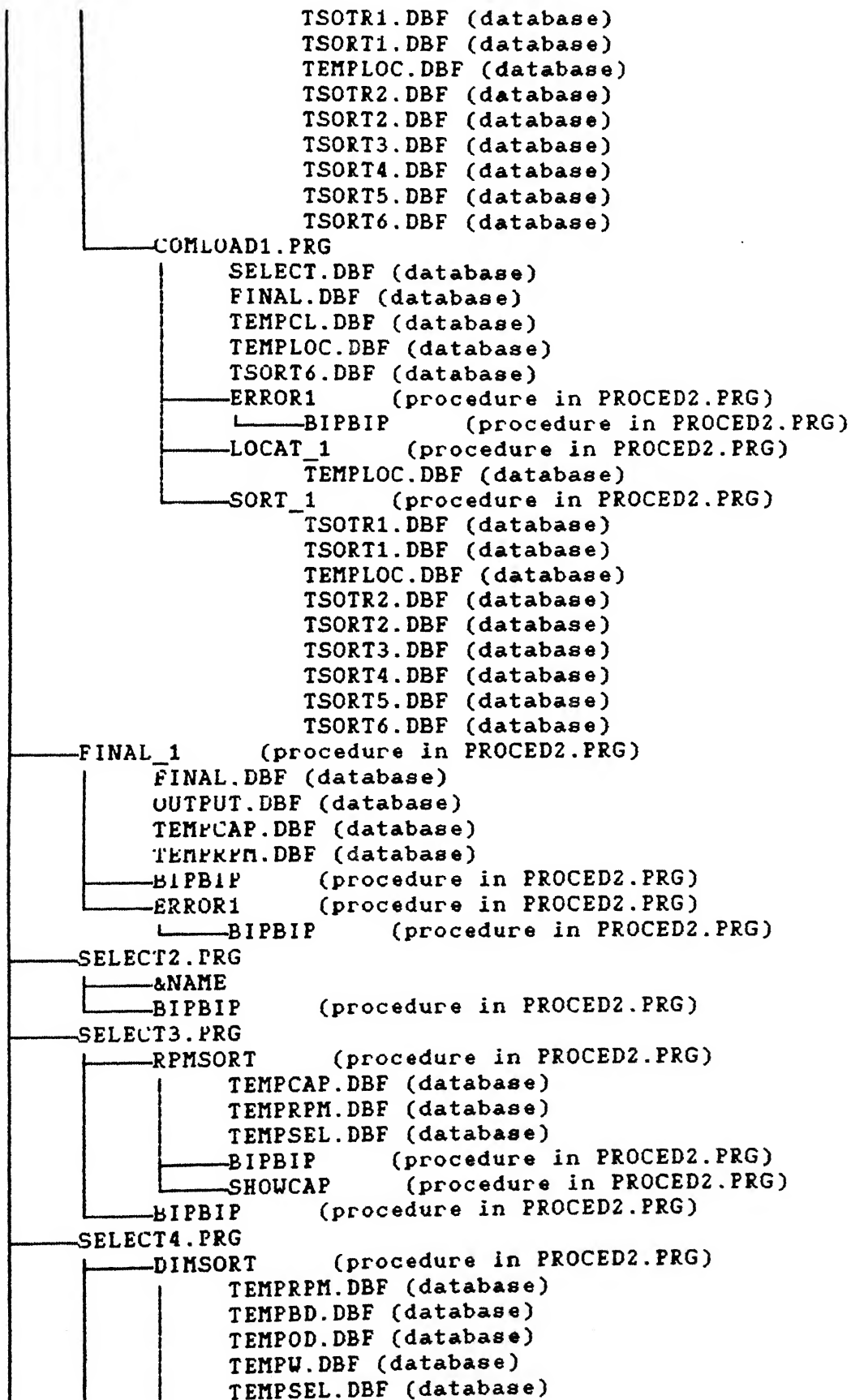
```

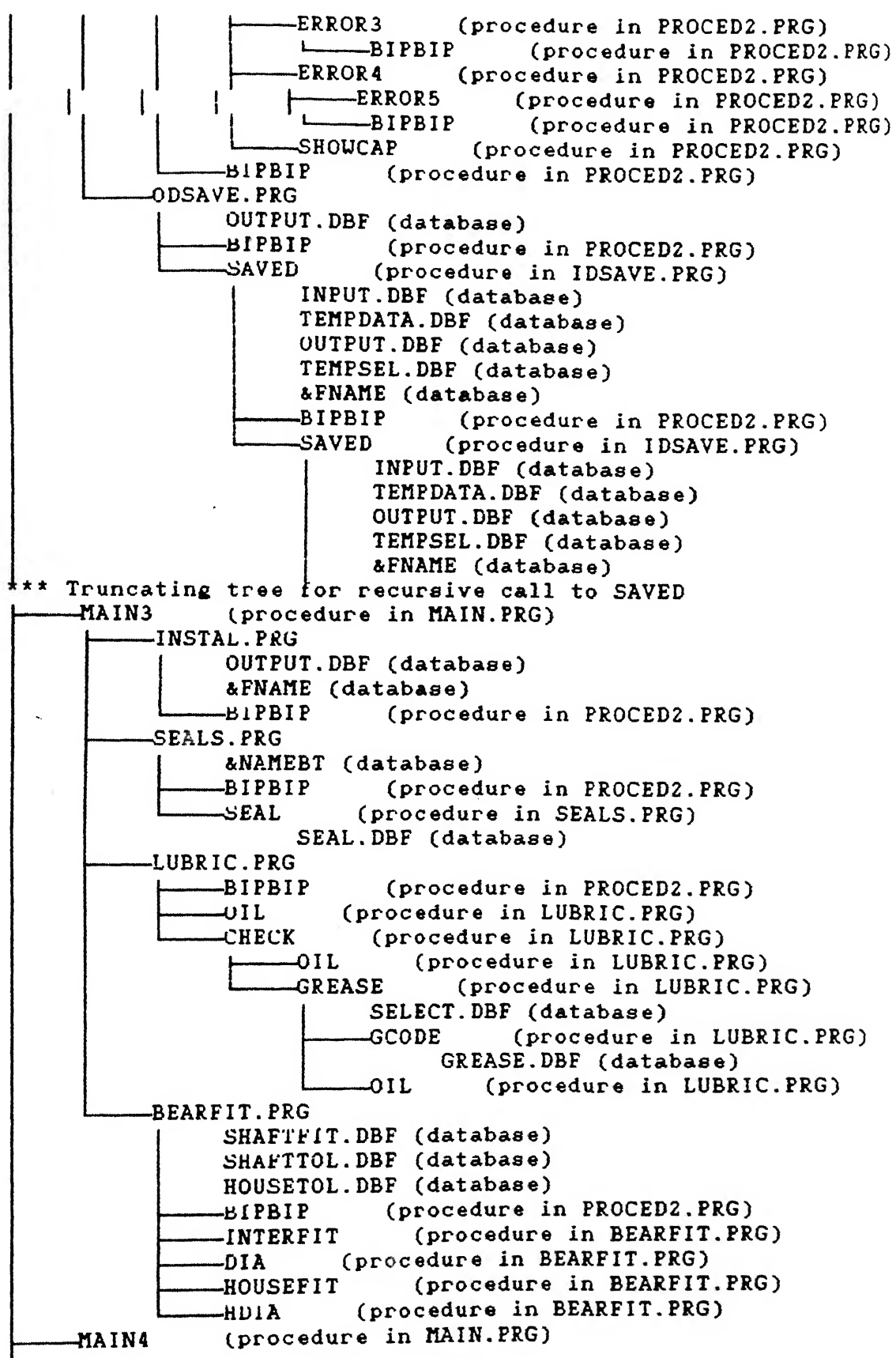
*** Truncating tree for recursive call to SAVED

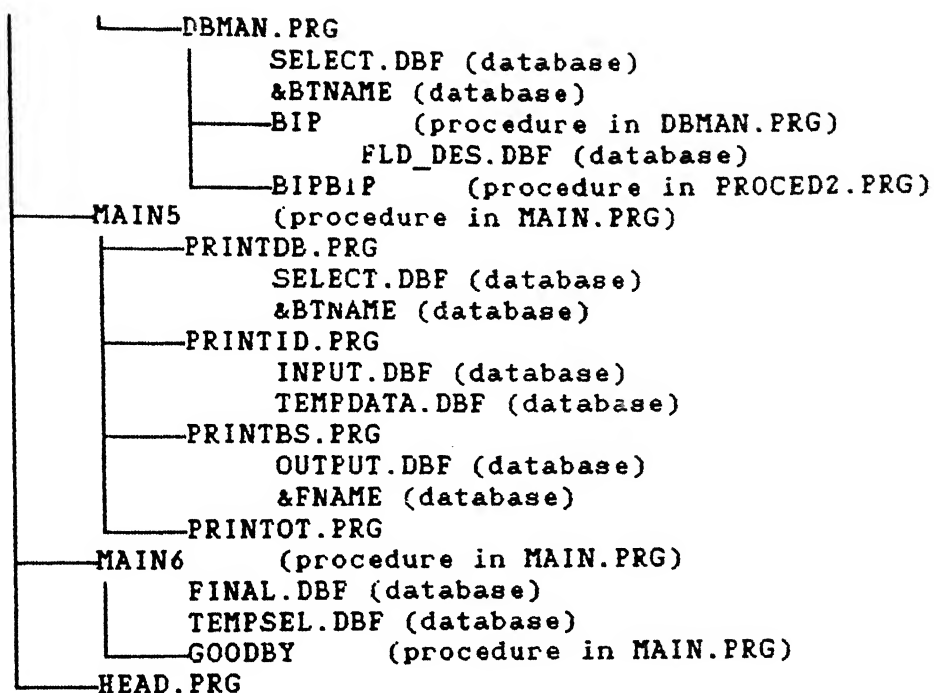
```

MAIN2      (procedure in MAIN.PRG)
  SELECT1.PRG
    INPUT.DBF (database)
    TMPSEL.DBF (database)
    OUTPUT.DBF (database)
    BIPBIP      (procedure in PROCED2.PRG)
    ONLYRL1.PRG
      SELECT.DBF (database)
      FINAL.DBF (database)
      TEMPORL.DBF (database)
      TEMPLOC.DBF (database)
      TSORT6.DBF (database)
      ERROR1      (procedure in PROCED2.PRG)
      BIPBIP      (procedure in PROCED2.PRG)
      LOCAT_1      (procedure in PROCED2.PRG)
      TEMPLOC.DBF (database)
      SORT_1      (procedure in PROCED2.PRG)
      TSOTR1.DBF (database)
      TSORT1.DBF (database)
      TEMPLOC.DBF (database)
      TSOTR2.DBF (database)
      TSORT2.DBF (database)
      TSORT3.DBF (database)
      TSORT4.DBF (database)
      TSORT5.DBF (database)
      TSORT6.DBF (database)
    ONLYTTL1.PRG
      SELECT.DBF (database)
      FINAL.DBF (database)
      TEMPTL.DBF (database)
      TEMPTL1.DBF (database)
      TSORT6.DBF (database)
      ERROR1      (procedure in PROCED2.PRG)
      BIPBIP      (procedure in PROCED2.PRG)
      SORT_1      (procedure in PROCED2.PRG)

```







3.3 Database Structures

* 61 databases in the system

-->(Macro used for following databases)

FINAL.DBF	ACBB1.DBF
TEMPSEL.DBF	ACBB2.DBF
TEMPLOC.DBF	ACBB3.DBF
TSOTR1.DBF	ACTBBS.DBF
TSORT1.DBF	ACTBBDD.DBF
TSOTR2.DBF	BRB.DBF
TSORT2.DBF	CRB1.DBF
TSORT3.DBF	CRB3.DBF
TSORT4.DBF	CRBDR.DBF
TSORT5.DBF	CRTB.DBF
TSORT6.DBF	DGBB1.DBF
OUTPUT.DBF	DGBB2.DBF
TEMPCAP.DBF	FPCBB.DBF
TEMPRPM.DBF	MB.DBF
ONEREC.DBF	NRB1.DBF
TEMP.DBF	NRB4.DBF
TEMPBD.DBF	NRB5.DBF
TEMPOD.DBF	NRTB.DBF
TEMPW.DBF	SABB.DBF
INPUT.DBF	SB.DBF
LIFEHELP.DBF	SRB1.DBF
TEMPDATA.DBF	SRTB.DBF
TMPSEL.DBF	TBB1.DBF
&FNAME	TBB2.DBF
&NAMEBT -----	TRB.DBF
SEAL.DBF	
SELECT.DBF	
GREASE.DBF	
SHAFTFIT.DBF	
SHAFTTOL.DBF	
HOUSE.TOL.DBF	
&BTNAME -----	
FLD_DES.DBF	
SLHELP.DBF	
TEMPORL.DBF	
TEMPTL.DBF	
TEMPTL1.DBF	
TEMPCL.DBF	

FINAL.DBF

Temporarily created database

Used by: FINAL_1 (procedure in PROCED2.PRG)
 : MAIN6 (procedure in MAIN.PRG)
 : ONLYRL1.PRG
 : ONLYTL1.PRG
 : COMLOAD1.PRG

TEMPSEL.DBF

Temporarily created database

Used by: CAPSORT2 (procedure in PROCED2.PRG)
 : RPMSORT (procedure in PROCED2.PRG)

APPENDIX B. BEARSEL SYSTEM DETAILS

Used by: CAPSORT2 (procedure in PROCED2.PRG)
 : RPMSORT (procedure in PROCED2.PRG)
 : DIMSORT (procedure in PROCED2.PRG)
 : MAIN6 (procedure in MAIN.PRG)
 : SAVED (procedure in IDSAVE.PRG)

TEMPLOC.DBF

Temporarily created database

Used by: LOCAT_1 (procedure in PROCED2.PRG)
 : SORT_1 (procedure in PROCED2.PRG)
 : ONLYRL1.PRG
 : COMLOAD1.PRG

TSOTR1.DBF

Temporarily created database

Used by: SORT_1 (procedure in PROCED2.PRG)

TSORT1.DBF

Temporarily created database

Used by: SORT_1 (procedure in PROCED2.PRG)

TSOTR2.DBF

Temporarily created database

Used by: SORT_1 (procedure in PROCED2.PRG)

TSORT2.DBF

Temporarily created database

Used by: SORT_1 (procedure in PROCED2.PRG)

TSORT3.DBF

Temporarily created database

Used by: SORT_1 (procedure in PROCED2.PRG)

TSORT4.DBF

Temporarily created database

Used by: SORT_1 (procedure in PROCED2.PRG)

TSORT5.DBF

Temporarily created database

Used by: SORT_1 (procedure in PROCED2.PRG)

TSORT6.DBF

Temporarily created database

Used by: SORT_1 (procedure in PROCED2.PRG)
 : ONLYRL1.PRG
 : ONLYTL1.PRG
 : COMLOAD1.PRG

OUTPUT.DBF

APPENDIX B. BEARSEL SYSTEM DETAILS

Structure for database :

Number of data records : 12

Field	Field name	Type	Width	Dec	Start	End
1	OPNAME	Character	10		1	10
2	IPNAME	Character	10		11	20
3	BTNAME	Character	10		21	30
4	RPMVALUE	Numeric	6		31	36
5	TMAX	Numeric	3		37	39
6	TMIN	Numeric	3		40	42
7	SF1	Numeric	3	1	43	45
8	RLVALUE	Numeric	10		46	55
9	TLVALUE	Numeric	10		56	65
10	RLD	Character	1		66	66
11	PARTROT	Character	1		67	67
12	LOCFUNC	Character	2		68	69
** Total **			70			

This database appears to be associated with index file(s):
: OUTPUT1.1DX

Used by: FINAL_1 (procedure in PROCED2.PRG)
: SELECT1.PRG
: ODSAVE.PRG
: INSTAL.PRG
: PRINTBS.PRG
: SAVED (procedure in IDSAVE.PRG)

TEMPCAP.DBF

Temporarily created database

Used by: FINAL_1 (procedure in PROCED2.PRG)
: CAPSORT1 (procedure in PROCED2.PRG)
: CAPSORT2 (procedure in PROCED2.PRG)
: RPMSORT (procedure in PROCED2.PRG)

TEMPRPM.DBF

Temporarily created database

Used by: FINAL_1 (procedure in PROCED2.PRG)
: RPMSORT (procedure in PROCED2.PRG)
: DIMSORT (procedure in PROCED2.PRG)

ONEREC.DBF

Temporarily created database

Used by: CAPSORT1 (procedure in PROCED2.PRG)

TEMP.DBF

Temporarily created database

Used by: CAPSORT1 (procedure in PROCED2.PRG)

TEMPBD.DBF

Temporarily created database

Used by: DIMSORT (procedure in PROCED2.PRG)

TEMPBD.DBF

Temporarily created database

Used by: DIMSORT (procedure in PROCED2.PRG)

TEMPW.DBF

Temporarily created database

Used by: DIMSORT (procedure in PROCED2.PRG)

INPUT.DBF

Structure for database :

Number of data records : 11

Field	Field name	Type	Width	Dec	Start	End
1	IPNAME	Character	10		1	10
2	NRPM	Numeric	1		11	11
3	RPMVALUE	Numeric	6		12	17
4	MEANRPM	Numeric	6		18	23
5	RPM1	Numeric	6		24	29
6	RPM2	Numeric	6		30	35
7	RPM3	Numeric	6		36	41
8	RPM4	Numeric	6		42	47
9	RPM5	Numeric	6		48	53
10	RPM6	Numeric	6		54	59
11	RPM7	Numeric	6		60	65
12	RPM8	Numeric	6		66	71
13	RPM9	Numeric	6		72	77
14	PER1	Numeric	2		78	79
15	PER2	Numeric	2		80	81
16	PER3	Numeric	2		82	83
17	PER4	Numeric	2		84	85
18	PER5	Numeric	2		86	87
19	PER6	Numeric	2		88	89
20	PER7	Numeric	2		90	91
21	PER8	Numeric	2		92	93
22	PER9	Numeric	2		94	95
23	NRL	Numeric	1		96	96
24	RLVALUE	Numeric	10		97	106
25	MEANRNL	Numeric	10		107	116
26	RL1	Numeric	10		117	126
27	RL2	Numeric	10		127	136
28	RL3	Numeric	10		137	146
29	RL4	Numeric	10		147	156
30	RL5	Numeric	10		157	166
31	RL6	Numeric	10		167	176
32	RL7	Numeric	10		177	186
33	RL8	Numeric	10		187	196
34	RL9	Numeric	10		197	206
35	PR1	Numeric	2		207	208
36	PR2	Numeric	2		209	210
37	PR3	Numeric	2		211	212
38	PR4	Numeric	2		213	214
39	PR5	Numeric	2		215	216
40	PR6	Numeric	2		217	218
41	PR7	Numeric	2		219	220
42	PR8	Numeric	2		221	222
43	PR9	Numeric	2		223	224
44	RLMAX	Numeric	10		225	234
45	RLMIN	Numeric	10		235	244

46	RLCON	Numeric	10		245	254
47	RLROT	Numeric	10		255	264
48	RLD	Character	1		265	265
49	NTL	Numeric	1		266	266
50	TLVALUE	Numeric	10		267	276
51	MEANTL	Numeric	10		277	286
52	TL1	Numeric	10		287	296
53	TL2	Numeric	10		297	306
54	TL3	Numeric	10		307	316
55	TL4	Numeric	10		317	326
56	TL5	Numeric	10		327	336
57	TL6	Numeric	10		337	346
58	TL7	Numeric	10		347	356
59	TL8	Numeric	10		357	366
60	TL9	Numeric	10		367	376
61	PT1	Numeric	2		377	378
62	PT2	Numeric	2		379	380
63	PT3	Numeric	2		381	382
64	PT4	Numeric	2		383	384
65	PT5	Numeric	2		385	386
66	PT6	Numeric	2		387	388
67	PT7	Numeric	2		389	390
68	PT8	Numeric	2		391	392
69	PT9	Numeric	2		393	394
70	TLMAX	Numeric	10		395	404
71	TLMIN	Numeric	10		405	414
72	TLCON	Numeric	10		415	424
73	TLROT	Numeric	10		425	434
74	TLD	Character	1		435	435
75	SHOK	Numeric	3	1	436	438
76	RLB	Numeric	2		439	440
77	A_1	Numeric	4	2	441	444
78	LHR	Numeric	7		445	451
79	IKM	Numeric	4	2	452	455
80	DIA	Numeric	4	2	456	459
81	LIFEIS	Numeric	8		460	467
82	TMPMAX	Numeric	3		468	470
83	TMPMIN	Numeric	3		471	473
84	FTEMP	Numeric	4	2	474	477
85	OP1	Numeric	1		478	478
86	OP2	Numeric	1		479	479
87	OP3	Numeric	1		480	480
88	OP4	Numeric	1		481	481
89	OP5	Numeric	1		482	482
90	OP6	Numeric	1		483	483
91	OP7	Numeric	1		484	484
92	OP8	Numeric	1		485	485
93	OP9	Numeric	1		486	486
94	PARTROT	Character	1		487	487
95	LOCFUNC	Character	2		488	489
96	BDMAX	Numeric	4		490	493
97	BDMIN	Numeric	4		494	497
98	ODMAX	Numeric	4		498	501
99	ODMIN	Numeric	4		502	505
100	WMAX	Numeric	3		506	508
101	WMIN	Numeric	3		509	511
** Total **			512			

This database appears to be associated with index file(s):
: INPUT1.IDX -

This database appears to be associated with multiple index file(s):
: INPUT.MDX

Used by: RELIBITY.PRG
: TEMPOR.PRG
: DIMEN1.PRG
: OPCON1.PRG
: DISPDATA.PRG
: IDSAVE.PRG
: SELECT1.PRG
: PRINTID.PRG
: SPD (procedure in SPEED.PRG)
: LOADTYPE (procedure in LOAD1.PRG)
: GETLIFE (procedure in LIFE1.PRG)
: SAVED (procedure in IDSAVE.PRG)
: SLOAD (procedure in SUDDEN.PRG)

LIFEHELP.DBF

Structure for database :

Number of data records : 123

Field	Field name	Type	Width	Dec	Start	End
1	USE	Character	44		1	44
2	OPER	Character	5		45	49
3	HOURS	Character	7		50	56
** Total **			57			

Used by: GETLIFE (procedure in LIFE1.PRG)

TEMPDATA.DBF

Temporarily created database

Used by: DISPDATA.PRG
: PRINTID.PRG
: SAVED (procedure in IDSAVE.PRG)

TMPSEL.DBF

Temporarily created database

Used by: SELECT1.PRG

&FNAME is a macro used for database
Temporarily created database

This database appears to be associated with report form(s):
: TEST.FRG

Used by: INSTAL.PRG
: PRINTBS.PRG
: SAVED (procedure in IDSAVE.PRG)

&NAMEBT is a macro used for a group of bearing databases (see database list)

Used by: SEALS.PRG
: &NAME (macro used for a group of PRG files; see PRG file list)

Structures of databases are as follows :

ACBB1.DBF

Structure for database:

Number of data records: 49

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	8		N
3	COMPANY	Character	5		N
4	BORE_DIA	Numeric	3		N
5	OUTER_DIA	Numeric	3		N
6	WIDTH	Numeric	3		N
7	C	Numeric	6		N
8	CO	Numeric	6		N
9	RPM_GRES	Numeric	6		N
10	RPM_OIL	Numeric	6		N
11	MASS	Numeric	6	3	N
** Total **			54		

ACBB2.DBF

Structure for database:

Number of data records: 47

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	8		N
3	COMPANY	Character	5		N
4	BORE_DIA	Numeric	3		N
5	OUTER_DIA	Numeric	3		N
6	WIDTH	Numeric	3		N
7	C	Numeric	6		N
8	CO	Numeric	6		N
9	RPM_GRES	Numeric	6		N
10	RPM_OIL	Numeric	6		N
11	MASS	Numeric	6	3	N
** Total **			54		

ACBB3.DBF

Structure for database:

Number of data records: 42

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	8		N
3	COMPANY	Character	5		N
4	BORE_DIA	Numeric	3		N
5	OUTER_DIA	Numeric	3		N
6	WIDTH	Numeric	4	1	N
7	C	Numeric	6		N
8	CO	Numeric	6		N
9	RPM_GRES	Numeric	6		N
10	RPM_OIL	Numeric	6		N
11	MASS	Numeric	6	3	N
** Total **			55		

ACTBBS.DBF

Structure for database:

Number of data records: 34

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N

2	B_NUMBER	Character	10		N
3	COMPANY	Character	3		N
4	BORE_DIA	Numeric	3		N
5	OUTER_DIA	Numeric	3		N
6	WIDTH	Numeric	2		N
7	A	Numeric	5	1	N
8	C	Numeric	6		N
9	CO	Numeric	6		N
10	MALOAD	Numeric	3		N
11	RPM_OIL	Numeric	4		N
12	RPM_GRES	Numeric	4		N
13	PRELOAD	Numeric	4	1	N
14	FR_MOMT	Numeric	4		N
15	MASS	Numeric	4	2	N
** Total **			63		

ACTBBDD.DBF

Structure for database:

Number of data records: 52

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	9		N
3	COMPANY	Character	3		N
4	BORE_DIA	Numeric	3		N
5	OUTER_DIA	Numeric	3		N
6	WIDTH	Numeric	3		N
7	C	Numeric	6		N
8	CO	Numeric	6		N
9	RPM_GRES	Numeric	5		N
10	RPM_OIL	Numeric	5		N
11	MASS	Numeric	5	2	N
** Total **			50		

BRB.DBF

Structure for database:

Number of data records: 78

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	7		N
3	DSGN_TB	Character	9		N
4	COMPANY	Character	3		N
5	BORE_DIA	Numeric	3		N
6	OUTER_DIA	Numeric	3		N
7	WIDTH	Numeric	2		N
8	C	Numeric	7		N
9	CO	Numeric	7		N
10	RPM_GRES	Numeric	4		N
11	RPM_OIL	Numeric	4		N
12	MASS	Numeric	5	2	N
** Total **			56		

CRB1.DBF

Structure for database:

Number of data records: 234

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	10		N
3	COMPANY	Character	3		N

4	BORE_DIA	Numeric	3		N
5	OUTER_DIA	Numeric	4		N
6	WIDTH	Numeric	3		N
7	C	Numeric	7		N
8	CO	Numeric	7		N
9	RPM_GRES	Numeric	5		N
10	RPM_OIL	Numeric	5		N
11	MASS	Numeric	7	3	N
** Total **			56		

CRB3.DBF

Structure for database:

Number of data records: 206

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	7		N
3	COMPANY	Character	3		N
4	BORE_DIA	Numeric	3		N
5	OUTER_DIA	Numeric	3		N
6	WIDTH	Numeric	3		N
7	C	Numeric	7		N
8	CO	Numeric	7		N
9	RPM_OIL	Numeric	5		N
10	RPM_GRES	Numeric	5		N
11	MASS	Numeric	6	3	N
** Total **			51		

CRBDR.DBF

Structure for database:

Number of data records: 60

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	12		N
3	DSGN_SB	Character	11		N
4	COMPANY	Character	3		N
5	BORE_DIA	Numeric	3		N
6	OUTER_DIA	Numeric	3		N
7	WIDTH	Numeric	3		N
8	C	Numeric	7		N
9	CO	Numeric	7		N
10	RPM_GRES	Numeric	5		N
11	RPM_OIL	Numeric	5		N
12	MASS	Numeric	5	2	N
** Total **			66		

CRTB.DBF

Structure for database:

Number of data records: 88

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	9		N
3	DSGN_ASSY	Character	10		N
4	COMPANY	Character	3		N
5	BORE_DIA	Numeric	3		N
6	OUTER_DIA	Numeric	3		N
7	WIDTH	Numeric	3		N
8	C	Numeric	7		N
9	CO	Numeric	7		N

10	A	Numeric	6	2	N
11	RPM_GRES	Numeric	4		N
12	RPM_OIL	Numeric	4		N
13	MASS	Numeric	6	2	N
** Total **			68		

DGBB1.DBF

Structure for database:

Number of data records: 214

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	9		N
3	COMPANY	Character	5		N
4	BORE_DIA	Numeric	3		N
5	OUTER_DIA	Numeric	3		N
6	WIDTH	Numeric	3		N
7	C	Numeric	6		N
8	CO	Numeric	6		N
9	RPM_GRES	Numeric	6		N
10	RPM_OIL	Numeric	6		N
11	MASS	Numeric	6	3	N
12	Z	Logical	1		N
13	ZZ	Logical	1		N
14	N	Logical	1		N
15	K	Logical	1		N
16	RS	Logical	1		N
17	RS2	Logical	1		N
18	NR	Logical	1		N
19	ZNR	Logical	1		N
** Total **			63		

DGBB2.DBF

Structure for database:

Number of data records: 31

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	8		N
3	COMPANY	Character	5		N
4	BORE_DIA	Numeric	3		N
5	OUTER_DIA	Numeric	3		N
6	WIDTH	Numeric	3		N
7	C	Numeric	6		N
8	CO	Numeric	6		N
9	RPM_GRES	Numeric	6		N
10	RPM_OIL	Numeric	6		N
11	MASS	Numeric	6	3	N
** Total **			54		

FPCBB.DBF

Structure for database:

Number of data records: 39

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	8		N
3	COMPANY	Character	5		N
4	BORE_DIA	Numeric	3		N
5	OUTER_DIA	Numeric	3		N
6	WIDTH	Numeric	3		N

7	C	Numeric	6		N
8	CO	Numeric	6		N
9	RPM_GRES	Numeric	6		N
10	RPM_OIL	Numeric	6		N
11	MASS	Numeric	6	3	N
** Total **			54		

MB.DBF

Structure for database:

Number of data records: 17

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	7		N
3	COMPANY	Character	3		N
4	BORE_DIA	Numeric	2		N
5	OUTER_DIA	Numeric	2		N
6	WIDTH	Numeric	2		N
7	C	Numeric	5		N
8	CO	Numeric	5		N
9	RPM_OIL	Numeric	5		N
10	RPM_GRES	Numeric	5		N
11	MASS	Numeric	5	3	N
** Total **			43		

NRB1.DBF

Structure for database:

Number of data records: 287

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	10		N
3	COMPANY	Character	5		N
4	BORE_DIA	Numeric	4		N
5	OUTER_DIA	Numeric	4		N
6	WIDTH	Numeric	4		N
7	C	Numeric	8		N
8	CO	Numeric	8		N
9	RPM_GRES	Numeric	9		N
10	RPM_OIL	Numeric	9		N
11	MASS	Numeric	6	3	N
** Total **			69		

NRB4.DBF

Structure for database:

Number of data records: 16

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	9		N
3	COMPANY	Character	5		N
4	BORE_DIA	Numeric	4		N
5	OUTER_DIA	Numeric	4		N
6	WIDTH	Numeric	3		N
7	C_R	Numeric	6		N
8	CO_R	Numeric	6		N
9	C_A	Numeric	5		N
10	CO_A	Numeric	5		N
11	RPM_GRES	Numeric	6		N
12	RPM_OIL	Numeric	6		N
13	MASS	Numeric	6	3	N

NRB5.DBF

Structure for database:

Number of data records: 13

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	9		N
3	COMPANY	Character	5		N
4	BORE_DIA	Numeric	4		N
5	OUTER_DIA	Numeric	4		N
6	WIDTH	Numeric	3		N
7	C_R	Numeric	6		N
8	CO_R	Numeric	6		N
9	C_A	Numeric	5		N
10	CO_A	Numeric	5		N
11	RPM_GRES	Numeric	6		N
12	RPM_OIL	Numeric	6		N
13	MASS	Numeric	6	3	N
14	A	Numeric	4	1	N
** Total **			71		

NRTB.DBF

Structure for database:

Number of data records: 26

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	11		N
3	DSGN_SH_W	Character	7		N
4	DSGN_HO_W	Character	7		N
5	DSGN_RA_W	Character	11		N
6	DSGN_TH_W	Character	11		N
7	COMPANY	Character	3		N
8	BORE_DIA	Numeric	3		N
9	OUTER_DIA	Numeric	3		N
10	WIDTH	Numeric	2		N
11	B_MM	Numeric	4	2	N
12	C	Numeric	6		N
13	CO	Numeric	6		N
14	RPM_GRES	Numeric	4		N
15	RPM_OIL	Numeric	4		N
** Total **			84		

SABB.DBF

Structure for database:

Number of data records: 116

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	11		N
3	DSGN_TB	Character	5		N
4	COMPANY	Character	3		N
5	BORE_DIA	Numeric	3		N
6	OUTER_DIA	Numeric	3		N
7	WIDTH	Numeric	3		N
8	C	Numeric	6		N
9	CO	Numeric	6		N
10	RPM_OIL	Numeric	6		N

12	MASS	Numeric	6	3	N
13	E	Numeric	4	2	N
14	Y1	Numeric	3	1	N
15	Y2	Numeric	3	1	N
16	Y0	Numeric	3	1	N
** Total **			73		

SB.DBF

Structure for database:

Number of data records: 86

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	17		N
3	COMPANY	Character	3		N
4	BORE_DIA	Numeric	3		N
5	OUTER_DIA	Numeric	3		N
6	WIDTH	Numeric	3		N
7	C	Numeric	6		N
8	CO	Numeric	6		N
9	RPM_GRES	Numeric	5		N
10	RPM_OIL	Numeric	5		N
11	MASS	Numeric	4	2	N
** Total **			57		

SRB1.DBF

Structure for database:

Number of data records: 167

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	8		N
3	COMPANY	Character	3		N
4	BORE_DIA	Numeric	4		N
5	OUTER_DIA	Numeric	4		N
6	WIDTH	Numeric	3		N
7	C	Numeric	8		N
8	CO	Numeric	8		N
9	RPM_OIL	Numeric	4		N
10	RPM_GRES	Numeric	4		N
11	MASS	Numeric	7	2	N
12	K	Logical	1		N
13	W33	Logical	1		N
14	E	Numeric	4	2	N
15	Y1	Numeric	3	1	N
16	Y2	Numeric	3	1	N
17	Y0	Numeric	3	1	N
** Total **			70		

SRTB.DBF

Structure for database:

Number of data records: 91

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	11		N
3	COMPANY	Character	3		N
4	BORE_DIA	Numeric	3		N
5	OUTER_DIA	Numeric	4		N
6	WIDTH	Numeric	3		N
7	C	Numeric	8		N

8	CO	Numeric	8		N
9	A	Numeric	7		N
10	RPM_OIL	Numeric	4		N
11	RPM_GRES	Numeric	2		N
12	MASS	Numeric	7	2	N
** Total **			62		

TBB1.DBF

Structure for database:

Number of data records: 124

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	7		N
3	DSGN_SPH	Character	6		N
4	COMPANY	Character	3		N
5	BORE_DIA	Numeric	3		N
6	OUTER_DIA	Numeric	3		N
7	WIDTH	Numeric	3		N
8	C	Numeric	6		N
9	CO	Numeric	7		N
10	A	Numeric	8	2	N
11	RPM_GRES	Numeric	4		N
12	RPM_OIL	Numeric	4		N
13	MASS	Numeric	5	2	N
** Total **			61		

TBB2.DBF

Structure for database:

Number of data records: 49

Date of last update : 09/10/95

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	7		N
3	DSGN_SPH	Character	5		N
4	COMPANY	Character	3		N
5	BORE_DIA	Numeric	3		N
6	OUTER_DIA	Numeric	3		N
7	WIDTH	Numeric	3		N
8	C	Numeric	6		N
9	CO	Numeric	7		N
10	A	Numeric	8	2	N
11	RPM_GRES	Numeric	4		N
12	RPM_OIL	Numeric	4		N
13	MASS	Numeric	5	2	N
** Total **			60		

TRB.DBF

Structure for database:

Number of data records: 102

Field	Field Name	Type	Width	Dec	Index
1	TYPE	Character	1		N
2	B_NUMBER	Character	8		N
3	COMPANY	Character	3		N
4	BORE_DIA	Numeric	3		N
5	OUTER_DIA	Numeric	3		N
6	WIDTH	Numeric	5	2	N
7	C	Numeric	7		N
8	CO	Numeric	7		N

9	RPM_GRES	Numeric	4		N
10	RPM_OIL	Numeric	5		N
11	MASS	Numeric	5	2	N
12	E	Numeric	4	2	N
13	Y2	Numeric	3	1	N
14	Y0	Numeric	3	1	N
** Total **			62		

SEAL.DBF

Structure for database :

Number of data records : 27

Field	Field name	Type	Width	Dec	Start	End
1	SEAL_TYPE	Character	18		1	18
2	OIL_LUB	Character	3		19	21
3	GRE_LUB	Character	3		22	24
4	SPEED	Character	5		25	29
5	TEMP	Character	4		30	33
6	DUST	Character	8		34	41
7	MOISTURE	Character	8		42	49
8	INSTAL	Character	8		50	57
9	SPACE	Character	8		58	65
10	OTHERS	Character	30		66	95
** Total **			96			

Used by: SEAL

(procedure in SEALS.PRG)

SELECT.DBF

Structure for database :

Number of data records : 27

Field	Field name	Type	Width	Dec	Start	End
1	DBNAME	Character	10		1	10
2	BEARNAME	Character	25		11	35
3	ORL	Numeric	1		36	36
4	OTL	Numeric	1		37	37
5	CL	Numeric	1		38	38
6	V1	Numeric	1		39	39
7	V2	Numeric	1		40	40
8	V3	Numeric	1		41	41
9	V4	Numeric	1		42	42
10	V5	Numeric	1		43	43
11	V6	Numeric	1		44	44
12	V7	Numeric	1		45	45
13	V8	Numeric	1		46	46
14	WEIGHTAGE	Numeric	3		47	49
15	RLCAP	Numeric	1		50	50
16	TLCAP	Numeric	1		51	51
17	CLCAP	Numeric	1		52	52
18	SLCAP	Numeric	1		53	53
19	LRATIO	Numeric	4	2	54	57
20	TLDIR	Character	1		58	58
21	LOCAT	Numeric	1		59	59
22	MAXTEMP	Numeric	3		60	62
23	MAXRPM	Numeric	5		63	67
24	FRELUB	Numeric	2		68	69
** Total **			70			

Used by: DBMAN.PRG

: ONLYR11.PRG
 : ONLYT11.PRG
 : COMLOAD1.PRG
 : GREASE

(procedure in LUBRIC.PRG)

GREASE.DBF

Structure for database :

Number of data records : 7

Field	Field name	Type	Width	Dec	Start	End
1	CODE	Character	8		1	8
2	THICKNER	Character	17		9	25
3	BASE_OIL	Character	12		26	37
4	TEMP_MIN	Numeric	3		38	40
5	TEMP_MAX	Numeric	3		41	43
6	RUST_PROT	Character	3		44	46
7	COST	Character	6		47	52
** Total **			53			

Used by: GCODE

(procedure in LUBRIC.PRG)

SHAFTFIT.DBF

Structure for database :

Number of data records : 25

Field	Field name	Type	Width	Dec	Start	End
1	BTNAME	Character	10		1	10
2	X1	Character	2		11	12
3	X2	Character	2		13	14
4	X3	Character	2		15	16
5	X4	Character	2		17	18
6	X5	Character	2		19	20
7	X6	Character	2		21	22
8	X7	Character	2		23	24
9	X8	Character	2		25	26
10	Y1	Character	2		27	28
11	Y2	Character	2		29	30
12	Y3	Character	2		31	32
13	Y4	Character	2		33	34
14	Y5	Character	2		35	36
15	Y6	Character	2		37	38
16	Y7	Character	2		39	40
17	Y8	Character	2		41	42
18	Z1	Character	2		43	44
19	Z2	Character	2		45	46
20	Z3	Character	2		47	48
21	Z4	Character	2		49	50
22	Z5	Character	2		51	52
23	Z6	Character	2		53	54
24	Z7	Character	2		55	56
25	Z8	Character	2		57	58
26	X9	Character	2		59	60
27	Y9	Character	2		61	62
28	Z9	Character	2		63	64
** Total **			65			

Used by: BEARFIT.PRG

SHAFTTOL.DBF

Structure for database :

Number of data records : 14

Field	Field name	Type	Width	Dec	Start	End
1	DES	Character	3		1	3
2	SD1	Character	7		4	10
3	SD2	Character	7		11	17
4	SD3	Character	7		18	24
5	SD4	Character	7		25	31
6	SD5	Character	7		32	38
7	SD6	Character	7		39	45
8	SD7	Character	7		46	52
9	SD8	Character	8		53	60
10	SD9	Character	8		61	68
11	SD10	Character	9		69	77
12	SD11	Character	9		78	86
13	SD12	Character	9		87	95
14	SD13	Character	9		96	104
15	SD14	Character	9		105	113
16	SD15	Character	9		114	122
17	SD16	Character	9		123	131
** Total **			132			

Used by: BEARFIT.PRG

HOUSETOL.DBF

Structure for database :

Number of data records : 6

Field	Field name	Type	Width	Dec	Start	End
1	DES	Character	3		1	3
2	HD1	Character	7		4	10
3	HD2	Character	7		11	17
4	HD3	Character	7		18	24
5	HD4	Character	7		25	31
6	HD5	Character	7		32	38
7	HD6	Character	7		39	45
8	HD7	Character	7		46	52
9	HD8	Character	8		53	60
10	HD9	Character	8		61	68
11	HD10	Character	9		69	77
12	HD11	Character	9		78	86
13	HD12	Character	9		87	95
14	HD13	Character	9		96	104
15	HD14	Character	9		105	113
16	HD15	Character	9		114	122
17	HD16	Character	9		123	131
** Total **			132			

Used by: BEARFIT.PRG

&BTNAME is a macro used for same databases shown in &NAMEBTThis database appears to be associated with report form(s):
: TEST.FRGUsed by: DEMAN.PRG
: PRINTDB.PRG-----
FLD_DES.DBF

Structure for database :

Number of data records : 16

Field	Field name	Type	Width	Dec	Start	End
1	FLDNAME	Character	10		1	10
2	DESCRIP	Character	40		11	50
** Total **			51			

Used by: BIP (procedure in DBMAN.PRG)

SLHELP.DBF

Structure for database :

Number of data records : 33

Field	Field name	Type	Width	Dec	Start	End
1	USE	Character	45		1	45
2	DUTY_TYPE	Character	13		46	58
** Total **			59			

Used by: SLOAD (procedure in SUDDEN.PRG)

TEMPORL.DBF

Temporarily created database

Used by: ONLYRL1.PRG

TEMPTL.DBF

Temporarily created database

Used by: ONLYTL1.PRG

TEMPTL1.DBF

Structure for database :

Number of data records : 16

Field	Field name	Type	Width	Dec	Start	End
1	DBNAME	Character	10		1	10
2	BEARNAME	Character	25		11	35
3	ORL	Numeric	1		36	36
4	OTL	Numeric	1		37	37
5	CL	Numeric	1		38	38
6	V1	Numeric	1		39	39
7	V2	Numeric	1		40	40
8	V3	Numeric	1		41	41
9	V4	Numeric	1		42	42
10	V5	Numeric	1		43	43
11	V6	Numeric	1		44	44
12	V7	Numeric	1		45	45
13	V8	Numeric	1		46	46
14	WEIGHTAGE	Numeric	3		47	49
15	RLCAP	Numeric	1		50	50
16	TLCAP	Numeric	1		51	51
17	CLCAP	Numeric	1		52	52
18	SLCAP	Numeric	1		53	53
19	LRATIO	Numeric	4	2	54	57
20	TLDIR	Character	1		58	58
21	LOCAT	Numeric	1		59	59
22	MAXTEMP	Numeric	3		60	62
23	MAXRPM	Numeric	5		63	67
24	FRELUB	Numeric	2		68	69
** Total **			70			

Used by: ONLYTL1.PRG

TEMPCL.DBF

Temporarily created database

Used by: COMLOAD1.PRG

B.4 System Files

Programs and procedures:

&NAME		(Macro used for following PRG fi
BEARFIT.PRG		{ ACBB1.PRG
BIP	(procedure in DBMAN.PRG)	ACBB2.PRG
BIPBIP	(procedure in PROCED2.PRG)	ACBB3.PRG
CAPSORT1	(procedure in PROCED2.PRG)	ACTBBS.D.PRG
CAPSORT2	(procedure in PROCED2.PRG)	ACTBBDD.PRG
CHECK	(procedure in LUBRIC.PRG)	BRB.PRG
COMLOAD1.PRG		CRB1.PRG
CON	(procedure in OPCON1.PRG)	CRB3.PRG
DBMAN.PRG		CRBDR.PRG
DECOR	(procedure in LOAD1.PRG)	CRTB.PRG
DIA	(procedure in BEARFIT.PRG)	DGBB1.PRG
DIMEN1.PRG		DGBB2.PRG
DIMSORT	(procedure in PROCED2.PRG)	FPCBB.PRG
DISPDATA.PRG		MB.PRG
ERROR1	(procedure in PROCED2.PRG)	NRB1.PRG
ERROR2	(procedure in PROCED2.PRG)	NRB4.PRG
ERROR3	(procedure in PROCED2.PRG)	NRB5.PRG
ERROR4	(procedure in PROCED2.PRG)	NRTB.PRG
ERROR5	(procedure in PROCED2.PRG)	SABB.PRG
FINAL_1	(procedure in PROCED2.PRG)	SB.PRG
GCODE	(procedure in LUBRIC.PRG)	SRB1.PRG
GETLIFE	(procedure in LIFE1.PRG)	SRTB.PRG
GOODBY	(procedure in MAIN.PRG)	TBB1.PRG
GREASE	(procedure in LUBRIC.PRG)	TBB2.PRG
HDIA	(procedure in BEARFIT.PRG)	TRB.PRG }
HEAD.PRG		
HOUSEFIT	(procedure in BEARFIT.PRG)	
IDSAVE.PRG		
INSTAL.PRG	(procedure in BEARFIT.PRG)	
INTERFIT		
LIFE1.PRG		
LOAD1.PRG	(procedure in LOAD1.PRG)	
LOADTYPE	(procedure in OPCON1.PRG)	
LOC	(procedure in PROCED2.PRG)	
LOCAT_1		
LUBRIC.PRG		
MAIN.PRG		
MAIN1	(procedure in MAIN.PRG)	
MAIN2	(procedure in MAIN.PRG)	
MAIN3	(procedure in MAIN.PRG)	
MAIN4	(procedure in MAIN.PRG)	
MAIN5	(procedure in MAIN.PRG)	
MAIN6	(procedure in MAIN.PRG)	
ODSAVE.PRG		
OIL	(procedure in LUBRIC.PRG)	
ONLYRL1.PRG		
ONLYTL1.PRG		
OPCON1.PRG	(procedure in TEST.PRG)	

PGPLAIN	(procedure in TEST.FRG)
POC	(procedure in OPCON1.PRG)
PRINTBS.PRG	
PRINTDB.PRG	
PRINTID.PRG	
PRINTOT.PRG	
PRNABORT	(procedure in TEST.FRG)
RELIBITY.PRG	
RESET	(procedure in TEST.FRG)
RLDIR	(procedure in LOAD1.PRG)
RLOAD	(procedure in LOAD1.PRG)
ROT	(procedure in OPCON1.PRG)
RPMSORT	(procedure in PROCED2.PRG)
RSUMM	(procedure in TEST.FRG)
SAVED	(procedure in IDSAVE.PRG)
SEAL	(procedure in SEALS.PRG)
SEALS.PRG	
SELECT1.PRG	
SELECT2.PRG	
SELECT3.PRG	
SELECT4.PRG	
SHOWCAP	(procedure in PROCED2.PRG)
SLOAD	(procedure in SUDDEN.PRG)
SORT_1	(procedure in PROCED2.PRG)
SPD	(procedure in SPEED.PRG)
SPEED.PRG	
SUDDEN.PRG	
TEMPAR.PRG	
TEST.FRG	
TEST.FRG	
TLDIR	(procedure in LOAD1.PRG)
TLOAD	(procedure in LOAD1.PRG)
UPD_VARS	(procedure in TEST.FRG)
VRLOAD	(procedure in PROCED2.PRG)
__DETAIL	(procedure in TEST.FRG)

Procedure files:

PROCED2.PRG
 MAIN.PRG
 SPEED.PRG
 LOAD1.PRG
 LIFE1.PRG
 OPCON1.PRG
 IDSAVE.PRG
 ODSAVE.PRG
 SEALS.PRG
 LUBRIC.PRG
 BEARFIT.PRG
 DBMAN.PRG
 SUDDEN.PRG
 TEST.FRG

Index files:

INPUT1.IDX

INPUT1.NDX
OUTPUT1.IDX
OUTPUT1.NDX

Multiple index files:
INPUT.MDX

Report forms:
TEST.FRG

Database files are shown in Database structure summary
Database files are shown in Database structure summary